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ORIGINAL ARTICLES.

I.—Colonel Feilden's Contributions to Glacial Geology.

By Professor T. G. Bonney, D.Sc., LL.D., F.R.S.

In 1877 and the following year Colonel H. W. Feilden published the results of his scientific investigations on the coasts of Smith Sound and the channel to the north.[1] In 1896 he made contributions to the geology of Kolguev, Waigats, and Novaya Zemlya in two other papers.[2] These are reprinted, together with one previously unpublished, in the appendix to Mr. H. J. Pearson's book, "Beyond Petsora Eastward" (1899). As the earlier work appears to have been forgotten by some writers upon glacial subjects, and the last-named might very easily escape their notice, I urged Colonel Feilden to give a summary of his chief results in some generally accessible periodical. Shortly afterwards, on being unexpectedly called away for service in South Africa, he requested me to undertake the task. For the sake of brevity, I restrict myself mainly to the investigations which throw light on the formation of Boulder-clay and its associated sands and gravels, because these establish two points: (1) that such deposits are sometimes formed beneath the sea; (2) that the land in these Arctic regions has been elevated, in places not less than a thousand feet, since either some time in or the close of the Glacial epoch. I draw especial attention to these points, because I have noticed in certain writings a tendency to take it for granted that Boulder-clays can only be the leavings of an ice-sheet upon the land, and to treat the idea of any such important change of level as an hypothesis so improbable as to be practically impossible. Hence I shall pass over sundry important observations which show that projecting rocks can be scratched, polished, and even rounded by the action of floating ice, and shall not enter upon "the literature of the subject," for it is of Colonel Feilden's work alone that I am concerned to give a summary. So, after remarking that he more than once calls attention to the amount of débris seen on floating ice,[3] I proceed to the observations bearing on these two points, not, however, arranging them under the separate heads, but giving them in geographical order.

[1] Ann. & Mag. Nat. Hist., ser. IV, vol. xx (1877), p. 489; Quart. Journ. Geol. Soc., vol. xxxiv (1878), p. 556. See also Nares' "Voyage to Polar Sea."

[2] Quart. Journ. Geol. Soc., vol. lii (1896), pp. 52, 721.

[3] "Beyond Petsora," pp. 250, 269, 270.

A. *Grinnell Land, etc.*[1]—Here we find abundant evidence that this "part of the land round the North Pole has been affected by a movement of upheaval since there was any subsidence." That statement is justified by the following observations:—(*a*) Fragments of mollusca and erratics are scattered over mountain tops and elevated plateaus. (*b*) Terminal moraines of ancient glaciers, containing numerous marine mollusca, are found above the present sea-level. (*c*) Raised beaches, with remains of such mollusca and with erratics stranded on their tops and slopes, occur tier above tier with great regularity. They appear to be frequent up to about 400 feet above sea-level, and the most elevated mentioned is at about 1,000 feet.[1] It consists of a clay containing ice-scratched erratics, with *Mya truncata*, *Saxicava rugosa*, *Astarte borealis*, and *Pecten Grœnlandicus*. A similar deposit with the same fossils also occurs here[2] just above sea-level; the latter resting on sandstone of Miocene age, the former on Azoic slates. Colonel Feilden also mentions a plateau at 800 feet, in which some remains of *Mya truncata* were found. Coniferous wood, still retaining its buoyancy and just like that stranded on the existing coastline, was found "at elevations of several hundred feet," and "there was no evidence in the mud beds of Grinnell Land to encourage the idea that any of these trees had grown *in situ*."[3]

B. *Arctic Norway.*—With this region Colonel Feilden has dealt briefly, because, as he says, numerous observers have already called attention to the raised beaches containing marine shells and the wave-marks on ice-worn crags high above sea-level, so that the fact of a general glaciation, followed by some submergence, and that by considerable elevation, can hardly be disputed.[4] But he mentions more particularly a conspicuous terrace on the mainland opposite to Tromsö, at the mouth of a valley about a quarter of a mile wide, which is continued north and south along the present coastline, its base being a few feet above present high-water mark. In 1894 a good section of this terrace, some 20 feet in height, was exposed. "From base to summit it is a homogeneous mass of blue clay, with boulders and stones interspersed throughout." These are ice-scratched, and "mollusca are abundant throughout the bed. *Cyprina Islandica* and *Pecten Islandicus*, partially retaining their colour, are common, likewise stones to which the 'bases' of a *Balanus* are attached." He also cites Professor A. Newton and Mr. Hudleston as having found in the Varanger Fjord, not far from Vadsö, the bones of a whale, about 50 feet above high-water mark and 200 yards from the shore, which they deemed to have been stranded in old times." Colonel Feilden himself found on Vardö a marine sand deposit, some 40 to 50 feet above sea-level, in which he collected bones of *Halichœrus gryphus* (grey seal), *Phoca hispida*

[1] Ann. & Mag. Nat. Hist., ut suprà, p. 483.
[2] In Watercourse Bay, Grinnell Land, lat. 81° 44′ N.
[3] Quart. Journ. Geol. Soc., vol. xxxiv (1878), p. 556; Nares, ut suprà, p. 327.
[4] A number of instances from different parts of Scandinavia are cited by J. F. Campbell: "Frost and Fire," vol. i, p. 351.

(the ringed seal), and *Gadus morrhua*, with *Buccinum undatum*, *Modiola modiolus*, and *Pecten Islandicus*.

C. *The Kola Peninsula.*—The coast scenery is bold, but the hills inland seem planed down to a general level, the highest summits apparently rising to 500 or 600 feet. In bays and indentations immense raised beaches are noticeable, especially to the westward of Cape Cherni. A "remarkable and prevailing feature of the country is the vast number of erratic blocks spread over it in every direction." [1] These are of local origin, so that they cannot be the leavings of a circumpolar ice-sheet. Mr. F. G. Jackson is quoted as having observed raised beaches and coniferous wood, proving an elevation of something like 250 feet eastward of the estuary of the Petsora river.

D. *Kolguev Island.*—This lies about 50 miles away from the mainland of Europe, and 130 miles south-west of the nearest part of Novaya Zemlya; the depth of the sea in the one case not being greater than 30 fathoms, in the other probably 70 fathoms. It is oval in shape, and about the area of Norfolk, being apparently "a vast accumulation of glacio-marine beds." [2] The highest ground in the island is about 250 feet above sea-level, but the shore-line is often formed by low cliffs of a bluish-grey clay, not exceeding 60 to 70 feet in height; the island becomes flatter towards the south-west, and there a considerable district is overlain by sea-sand. The ground is furrowed by ravines, often rather short, which have been cut by rivulets and afford sections of the clay, their beds being strewn with stones and boulders derived from it. These vary in form from angular to rounded and polished, a large proportion being ice-scratched. "The medley of rocks represented is remarkable—granites and gneisses, limestones Silurian and Carboniferous, grits, quartzites, porphyries, etc.; they vary in size from walnuts to large dimensions.[3] They do not exhibit the slightest tendency to form lines of horizontal deposit in the clay," the matrix of which shows no signs of stratification or of disturbance. "My opinion is, that all have been dropped from floating ice intermittently and tranquilly . . . . Not unfrequently the clays pass into horizons of a more sandy composition, although so insensibly that the alteration is evidenced more by the change in colour than by any definite lines of demarcation." Deposit has been continuous; there are no beds of gravel traversing the clays as in Grinnell Land and at Smith Sound, where the horizons of clay, sand, and gravel are often distinctly defined. No drift-wood occurs; the remains of mollusca are not common, and for the most part fragmentary. The following were obtained: *Natica affinis*, fragments of gasteropod (*Sipho*? sp.), *Saxicava arctica*, *Astarte compressa* and *borealis*, *Mya arenaria*, and fragments of *Mya*, sp. The clay, Colonel Feilden remarks, is not

[1] Some peculiarities in their distribution are mentioned, but on these it is needless to dwell.

[2] No rock of greater solidity was anywhere seen *in situ*.

[3] One, of a hard yellow sandstone, polished, scored, and striated, measured 15 × 9 × 6 feet.

similar to the "firm, tough, tenacious, strong" material called 'till' in Scotland, but rather resembles the Boulder-clays of the Yorkshire coast and the Chalky Boulder-clay of Norfolk.[1] He regards it as a glacio-marine deposit, not that of an ice-sheet, and "formed under conditions similar to those which at present exist in Barents Sea."

E. *Waigats Island.* — This is about sixty miles in length and twenty in breadth. Its ridges probably in no case exceed 300 feet, and, as a rule, are much lower. Specimens collected *in sitû* represent: limestones, sometimes dolomitic; argillite and green schistose rocks, perhaps compact basic igneous rocks modified by crushing. The first-named bear a general resemblance to some of the Carboniferous limestones of Britain, and contain foraminifera which make their identification highly probable.[2] The valleys and troughs are filled by clay and sand, mostly the former, which is of the same character as that now forming under water in the bays and around its shores. These deposits at Cape Matinsela exceed 100 feet in thickness. They were followed for several miles on both sides of the Cape, forming low hills 50 to 100 feet in height along the coast (the result of denudation). Where examined, they showed no definite signs of stratification, and contained large ice-polished boulders;[3] in fact, they resemble the Kolguev clay. No shells of marine mollusca were found in them, but samples submitted to Mr. Joseph Wright contained foraminifera and sponge spicules, the latter in abundance. "These Matinsela beds pass by almost imperceptible gradations into the grey marine clay, with shells of recent mollusca, that now forms the surface of the present tundra land." This is rich in foraminifera, and is the most widely dispersed deposit, for it is spread over the tundra land of Arctic Russia, over Waigats, and over Novaya Zemlya up to an altitude of at least 500 feet, always forming the surface layer. "Precisely the same clay comes up in the dredge or on the flukes of the anchor in the Straits of Yugov, in Dolga Bay, and other anchorages on the coasts of Waigats." Colonel Feilden also calls attention to the effects of floating ice in smoothing, polishing, and scoring projecting rocks, and in thrusting up mounds of gravel "many feet beyond tide line, both here[4] and in Novaya Zemlya."[5]

F. *Novaya Zemlya.*—Colonel Feilden landed at places on the west coast of the southern island, on the east coast of the northern one as far as Pachtussoff Island, and in Matyushin Shar, the dividing strait. On Gooseland and the islands in Kostin Shar, deposits of Boulder-clay lie in their undulations and hollows, a depth of 20 feet being shown. The clay was of the same colour as the rock on

[1] See "Beyond Petsora," pp. 238, 239, for a note on the composition of the Kolguev deposits.

[2] Ut suprà, pp. 279, 280. Silurian and possibly Lower Devonian rocks occur at Cape Greben, at the south end of the island; see E. T. Newton, pp. 287–294.

[3] The following specimens were taken from erratics: granite (three varieties), felspathic grit (three varieties), limestone (two varieties, one shown by fossils to be Carboniferous or possibly Devonian in age); fragment of a guard of a belemnite, probably Jurassic; lignite, probably not earlier than Tertiary age.

[4] Ut suprà, pp. 270, 271.

[5] Ut suprà, pp. 249–254.

which it rests; the included stones were angular fragments of that rock; none were rounded or ice-scratched. In many places it is "full of shells of marine mollusca, *Saxicava arctica* predominating, though I found other species common enough. In some localities one might gather these shells by the bushel, few of them broken, never triturated, and in some cases the two valves are in contact." Raised beaches were observed in all the above-named parts of Novaya Zemlya, but more particular descriptions are given of those around Beluga Bay in the Matyushin Shar, and on the eastern outlet of that strait. The beaches, four or five in number, rise one above the other in a series of terraces with broad level surfaces, separated by slopes of about 100 feet in height, the most elevated being about 500 feet above present sea-level. Sections have been cut in them by streams, which disclosed accumulations of shells, chiefly *Saxicava arctica* and *Astarte borealis*. "The 100-foot terrace has a common origin with a series of outliers in the shape of rounded hills and eminences, now detached to some distance from the line of terrace and bordering the present sea-shore. A section in one showed it to be composed of the same materials, viz., rounded stones, sand, and gravel." At elevations up to 1,000 feet on the hillsides bounding the Matyushin Shar, Colonel Feilden came across "patches of rounded waterworn pebbles, that seemed to be remnants of still loftier sea beaches," but they were so overwhelmed by the screes falling from the upper parts of the mountains, that they could not be traced very far in a horizontal direction.

Mr. Joseph Wright, F.G.S., has written a most valuable report on the foraminifera from these deposits in Novaya Zemlya and Waigats Island. The samples of clay, twenty-six in number, twelve from various parts of the Cape Matinsela terraces, averaged about 2½ oz. from each locality. It may suffice to give a brief abstract of the general results, referring the reader to the report[1] for particulars. In Waigats Island, clay or mud with shells at 50 feet elevation from four localities yielded foraminifera: one, two genera; another, three; a third, three genera; individuals in all cases being rare; but the fourth locality afforded 8 genera and 14 species, four of these being common, besides frequent sponge spicules.[2] Clay with shells, 100 feet elevation, gave 6 genera and 9 species, only one of them common. Eleven small samples from the terraces and deposits of Cape Matinsela, which rise to the height of 150 feet, furnished only two foraminifera, of the same number of genera, but sponge spicules were very common. On the Russian mainland, near Habarova, clay with shells, forming the surface soil of the tundra, at 25 feet elevation, contained 9 genera and 13 species, six of them common, besides frequent sponge spicules and very numerous ostracods. From the same neighbourhood, clay with shells at 50 feet elevation afforded 3 genera and 4 species. The specimens from Matyushin Shar, Novaya Zemlya, gave the following results:—East side of Beluga Bay, 100-foot terrace, 3 genera and

[1] Ut suprà, pp. 297–310.

[2] In the remainder of this summary, the omission of any statement means "rare."

species; two openings in a terrace, composed of a stiff yellow clay, at about the same elevation, afforded in one case one genus, in the other two genera. Clay and sand from a terrace 130 feet high contained 7 genera, 13 species, with one specimen of an ostracod and a few sponge spicules. Shell bed, belonging to the 300 feet mud beds of Beluga Bay, but three miles inland, contained a great profusion of foraminifera, many of them being large in size and in fine preservation. They represented 15 genera and 34 species. A very few echinus spines also occurred. Clay with shells from the 500-foot terrace contained 10 genera and 24 species, twelve being common, and half of these estimated as making up between them 840 specimens, all the rest together amounting to 75. Ostracods were rare, echinus spines more abundant, the specimens being large. The last sample comes from Nameless Bay, west coast of Novaya Zemlya proper, 250 feet elevation. In it foraminifera were abundant, numbering 8 genera, 13 species. To sum up in Mr. Wright's words:—"Foraminifera occurred in all . . . . ; in nine of them they were very rare or rare, in one of them they were plentiful, in the other five they were in great profusion. Sponge spicules in a somewhat fragmentary state were found in nearly all of them, and ostracods and spines of echinoderms in several.[1] . . . . Nearly all the stones which occurred in the clays were more or less rounded, and presented the appearance of having been worn by marine action; in a few cases they were smoothed and striated, as if by the action of ice. The conditions under which these clays were deposited must have been very varied, as in some of them foraminifera are abundant, whilst in others they are extremely rare. When they are abundant it may be inferred that the clays were laid down in quiet water or in sheltered bays, and not subjected to the rapid running of currents or tides; and when they are few it may be presumed that the reverse was the case."

In this summary I have restricted myself to Colonel Feilden's observations of facts, excluding inferences, except in one or two cases where they express the impression produced by the general aspect of a deposit, which, from an experienced observer, has almost an equal value. I may, however, add that he saw no reason for attributing any of the deposits on the low islands or the mainland tundra to the action of a great polar ice-sheet. As Novaya Zemlya, at least in the centre and north, is mountainous, the summits rising to not less than 4,000 feet above sea-level, it must have always been a nucleus of outflowing ice,[2] so that the materials of its terraces cannot have made a subglacial journey uphill from the bed of the sea. Such an hypothesis would be more than ever improbable in the narrow strait of Matyushin Shar.

[1] A few samples of the mud of the sea-bed were collected and examined. They were found to correspond generally with the above-named.

[2] The interior of Lütke Land at the present day is covered with ice which probably forms a single sheet, "similar to that enveloping Greenland, but on a smaller scale."—Pearson in "Beyond Petsora," p. 150.

II.—The Order of Consolidation of the Mineral Constituents of Igneous Rocks.

By Professor W. J. Sollas, LL.D., D.Sc, F.R.S., V.P.G.S.

THE order in which the various mineral constituents of an igneous rock may crystallize out from an igneous magma offers to the petrologist a problem of great difficulty and complexity. It is generally admitted that the order of consolidation is not wholly determined by the order of the fusion-points of the constituents, and with this admission the fusion-points have come to be consistently disregarded, as though they might safely be left out of account. That this is not the case has of late become strongly impressed upon me, especially after a consideration of the important data obtained by Mr. Ralph Cusack, B.A.,[1] who, by means of Professor Joly's meldometer, has determined the precise temperature of fusion of most of the rock-forming minerals.

In the following table I have arranged the more important of the minerals in question in the order of their fusion-points, as determined by Mr. Cusack.

	Fusion Point.		
Zircon ...	infusible.	Augite Hornblende	1188° to 1200°.
Quartz ...	1425°.		
Olivine ...	1363° to 1378°, softens at 1342° C.	Albite ...	1172°.
		Microcline ...	1169°.
Leucite ...	1298°.	Adularia ...	1164° to 1168°.
Enstatite ...	1295°.	Sphene ...	1127° to 1142°.
Labradorite ...	1223° to 1235°.	Sodalite ...	1127° to 1133°.
Apatite ...	1221° to 1227°.	Nepheline ...	1059° to 1078°.

If for the moment we disregard quartz, there is seen to be on the whole a general correspondence between the order of fusion-points and the order of consolidation; but this is by no means constant, and is subject to several important exceptions. Zircon is well known as a very early product of most magmas, and this accords with the very high temperature of its fusion-point. Apatite and sphene, however, often appear earlier than their fusion-point would indicate. Olivine, with the highest fusion-point among the silicates, also usually crystallizes out at an early stage, though not always before leucite, of which the fusion-point is lower by 100° C. It is true that petrographers are not wholly agreed as to the relation in which leucite stands to olivine in this respect, but the balance of evidence appears to show that both may crystallize out together, or that leucite may actually precede olivine. It is of importance to notice in connection with this that the leucite and olivine on which Mr. Cusack experimented were both derived from Vesuvian rocks; had this not been the case the argument might have been maintained that the particular species of these minerals which enter into the composition of the lavas of Vesuvius may differ in chemical composition from those of which the fusion-points have been determined, and therefore may differ also in fusion-point. Enstatite

[1] Proc. Roy. Irish Acad., ser. III, vol. iv, p. 411 (1897).

occupies a position in the order of consolidation corresponding with that of the order of fusion. Similarly labradorite, with a fusion-point between enstatite and augite, usually follows enstatite and precedes augite in order of consolidation. That it is as a rule extricated from the magma before augite, is illustrated by the frequent occurrence of ophitic structure in dolerite. Albite fuses at a lower temperature than augite, and usually crystallizes after it.

It would be natural to suppose that the species of felspar intermediate with labradorite and albite in composition would be also intermediate as regards their fusion-points, and if so, the irregularities which distinguish the succession of plagioclase and pyroxene might find an explanation in the fact that the fusion-point of augite stands almost midway between that of albite and labradorite.

The potash felspars have a lower fusion-point than albite, and, as is well known, generally succeed it in order of consolidation.

The order of fusion of orthoclase, sodalite, and nepheline is repeated in the order of consolidation of these minerals in nepheline basanite; but an anomaly is presented in the case of some examples of æleolite syenite, in which nepheline and leucite precede orthoclase in order of consolidation. To this allusion will be made later. The most important exception to the rule that the order of fusion corresponds to the order of consolidation is afforded by quartz, which with a fusion-point of 1425° crystallizes later than orthoclase with a fusion-point of only 1164°–1168°. An explanation, however, may be found for this, and if admitted may throw light on some other inversions of the rule. The statement of Zirkel will, I think, be generally conceded. "A mineral may crystallise out from the molten silicate-magma at the most various temperatures—naturally, however, never *above* its own fusion point."[1]

The fact to be explained therefore in the case before us is the consolidation of quartz at a temperature below the fusion-point of orthoclase, i.e. at least 260° below its own fusion-point. In the report of the meeting of the British Association for 1882 will be found an account of some experiments made by Mr. Hunter for a committee of the Association (p. 239). Some chemically pure silica, "prepared by precipitation from sodium silicate with hydrochloric acid, evaporation to dryness, thorough washing, and subsequent ignition, was placed in a sealed iron-tube and heated with water to 300° C. for two days. At the conclusion of the experiment the impalpable powder of silica was found to have caked together into a white opaque granular mass." It consisted of anhydrous silica, as was proved by chemical investigation. The results of an examination which I made under the microscope were as follows:—"It was found to have passed into a state of glass. The glass is transparent and colourless and hard enough to scratch ordinary window glass; it is, however, filled with innumerable oval and tubular cavities, so as to resemble pumice, and it is to them that it owes its whiteness and opacity when seen by the unassisted eye."

[1] Zirkel: "Lehrbuch der Petrographie," 1893, vol. i, p. 728.

These facts prove that in the presence of water anhydrous silica is rendered fluid at a temperature so low as 300° C. Whether or not under these circumstances water enters into its constitution is not known, but after consolidation it consists of truly anhydrous silica (SiO_2), though in a state of glass.

That water is associated with the quartz of granite and other plutonic rocks is well known, for this mineral is the chief home of fluid cavities, which recall those described in the glassy silica of Mr. Hunter's experiment, though in the quartz of igneous rocks they are relatively far less abundant. The old explanation of the late consolidation of quartz, which rested on the suggestion that solution played as important a part as fusion in contributing to the fluidity of igneous magmas, is to a certain extent thus supported by experimental evidence. The mistake of the older school of petrologists lay in attributing too subordinate a rôle to fusion, which we now know plays the chief part; but in making this nearer approach to the truth there seems to me a possibility that we may have fallen into the other extreme of neglecting to take into consideration the influence of water, which may have played an important though minor part. If this can be shown to be the case we shall be provided with an explanation of anomalies, which hitherto have resisted all analysis. To return to the case of æleolite syenite, examples are known of this rock in which the several minerals have crystallized out in the order of their fusion-points; on the other hand, examples can as certainly be cited in which this order has been reversed, so that sodalite has followed æleolite; æleolite, orthoclase; and orthoclase, plagioclase felspar.

No satisfactory explanation has yet been offered of this and numerous similar cases, but if the order which follows that of the fusion-points be looked upon as the normal, our task will be simplified, since it will be reduced to finding special explanations of particular cases. It is possible that these explanations will not always be of the same nature, and I do not propose now to enter into a detailed study of this question, but I may perhaps be allowed to point out that several hypotheses would appear to be excluded. The influence of the chemical constitution of the magma is sometimes alluded to in general terms, though rarely analyzed in detail. That it must be very limited in its application is suggested by the experiment of Fouqué and Levy, in which they showed that in the case of two fused mixtures, one consisting of equal parts of anorthite and augite and the other with twice as much anorthite as augite, the order of consolidation was the same for both, the anorthite, as might have been expected from its higher fusion-point, crystallizing out in both cases before the augite. Change of pressure is sometimes invoked, and considering the very large reduction in volume which accompanies the consolidation of fused silicates this might naturally be supposed to have some effect. If, however, such were the case some law should be found distinguishing the order of consolidation of minerals in a plutonic magma from that in a volcanic flow; but hitherto no constant difference has been

discovered. The effects of 'mixture' have also been appealed to, and it is possible that in some cases the minerals which consolidate out of turn may be 'xenocrysts,' derived from some ingested foreign rock. But as a general explanation this admittedly cannot be maintained.

No doubt difficulties will also be found to attend any attempt to explain anomalies by the presence of water, but it appears to me that the attempt is worth suggesting. The problem as it now presents itself is to show why certain minerals retain the fluid state at a temperature below, often far below, that of the fusion-point: thus, in the case of some examples of æleolite syenite the question is why plagioclase felspar crystallized out at a lower temperature than orthoclase, orthoclase at a lower temperature than sodalite, and sodalite than æleolite. Can this be due to the effects of included water? To answer this question definitely might not be difficult by means of experiment. The determination of the fusion-points having been accomplished, the next step that awaits us is the determination of the temperatures at which the minerals in question crystallize from solution. An investigation in this direction could not fail to give interesting results.

In conclusion, it may be pointed out that the results definitely obtained in the case of quartz indicate that the temperature of consolidation of granite might naturally be expected to be below that of dolerite. The quartz of granite has consolidated at a temperature below that of orthoclase and *à fortiori* below that of plagioclase and pyroxene. The temperatures of fusion of these two rocks, as observed in the laboratory, stand in inverse order to the temperatures at which they consolidate in nature, owing to the fact that in the case of fusion by artificial means water plays no part.

III.—A Word on Geological Hypothesis.

By Professor H. Macaulay Posnett, LL.D., etc.

"SCIENTIFIC men," said Professor Thomas H. Huxley,[1] "get an awkward habit—no, I won't call it that, for it is a valuable habit—of believing nothing unless there is evidence for it; and they have a way of looking upon belief which is not based upon evidence, not only as illogical, but as immoral."

Quite so. There is no higher conception of truth—the most exact knowledge attainable at the given time and place—no nobler practice of truthfulness—the unflinching utterance of the most exact knowledge we possess—than our best men of science constantly display. And it is just because they are the world's highest guardians of truth, the world's noblest exponents of truthfulness, that our men of science are bound by the laws of their order to set the study of facts before the acceptance or retention of any theory, to expose in the clearest light any weak points in reasoning that on the whole receives their approval, to boldly dwell upon the

[1] "Science and Hebrew Tradition," p. 65.

hypothetical character of every hypothesis they make, and never to leave hypothesis or assumption to the tardy discovery of those who study their works.

There may indeed have been a time when theological dogmatism was strong enough to provoke a sort of scientific dogmatism by way of counterpoise. But neither theology nor any other power in the sphere of popular thought can now restrict the freedom of scientific discovery or teaching in the British Empire. Science nowadays can well afford to point out her own shortcomings, and can do so better than any of her foes. To some of these shortcomings it is my present purpose to refer.

1. Our geological textbooks sometimes show too much eagerness to impart the results of discovery or hypothesis without any adequate statement of the facts or the reasoning upon which these discoveries and hypotheses rest. Evidences are always the primary, never the secondary, material of science as a body of more or less probable truths. Evidences, therefore, are very improperly handled when they are relegated to a secondary place. If, for example, a geological writer accepts the theory of the origin of hot springs as due to the escape of subterraneous gases, it is his duty not merely to state the theory but to add the evidences for and against its truth. We may be told that makers of textbooks have not sufficient space for the statement of evidences, but the answer is plain: either do not put forward the theory at all, or give as fully as possible what must always be of higher value—the facts upon which the theory rests.

2. Many of our scientific manuals suggest, without positively claiming, a degree of foreknowledge that is not really as yet within our reach. An experience in New Zealand will illustrate the sort of claim I have in mind. Shortly after the Tarawera eruption of June, 1886, some professors of science proceeded to the Rotorua district and there held a Maori meeting. The Maoris were told that, the lines of volcanic energy having such and such directions, they need entertain no fears of a recurrence of the late disaster—"they might plant their kumeras (sweet potatoes) in peace." Hereupon an old Maori chief, with the usual sagacity of his race, rose and remarked, "If the volcano-doctors know so much about what is to be, what a pity it was they did not come and forewarn us of the eruption." Needless to say, the 'volcano-doctors' had no reply; and in our civilized views of volcanic forces it would be far better to own ignorance than to even hint a claim to foresight where it does not as yet exist. It is worth adding that, not very far from the Rotorua district, in the now famous goldfields of the Thames, an eminent but dogmatic and hasty geologist many years ago prophesied that no gold could there ever be found.

3. The points at which geological study touches other sciences and needs their aid are too frequently obscured, understated, or even completely omitted in some geological textbooks. I have now before me a textbook written by a very able geologist. I open it at the chapter entitled "The Earliest Conditions of the Globe." Here I find a lucid statement of the Nebular Hypothesis — but

unaccompanied by any detail of the grounds upon which that hypothesis rests — and of the accepted periods of the geological record; but not a word about the astronomer's theory of the diminishing velocity of the earth's rotation produced by tidal friction, not a word on the important bearing of this theory on the primary geological problem, the age of the earth.

I choose this example—the time problem—because there are other sciences dependent for the settlement of this problem on the joint labours of geologist, astronomer, and physicist, and my example therefore illustrates the paramount importance of such joint study. "The biologist," said Professor Huxley,[1] "knows nothing whatever of the amount of time which may be required for the process of evolution. . . . . A biologist has no means of arriving at any conclusion as to the amount of time which may be needed for a certain quantity of organic change. He takes his time from the geologist."

This interdependence of scientific studies must be fully recognized by the geologist, both for his own sake and for the sake of others. He cannot afford to ignore any knowledge possessed by any other science if that knowledge has an important bearing on his own pursuits. Always he must be ready to learn from astronomer, physicist, chemist; and though to the last of these three he has been generally willing to acknowledge his many obligations — obligations likely to be increased in the near future—he has but too often displayed a desire to avoid the physical and astronomical aspects of geological science. If I am told that I am asking too much from the geologist—making him a kind of universal genius like the ideal poet described in Johnson's "Rasselas"— I reply, "Nothing of the sort; I am merely insisting upon the absolute necessity that any first-rate geological discoverer or teacher shall keep steadily in view the points at which other sciences may increase his light, and never rest satisfied with either his discoveries or his teaching until he has assured himself that he has borrowed whatever light they can at present afford him."

4. Sir Archibald Geikie[2] reminds us that the various processes of geological changes occurring at the present day "gain enormously in interest for the student of nature when he reflects that in watching the geological operations of the present day he is brought face to face with the same instruments whereby the very framework of the continents has been piled up and sculptured into the present outlines of mountain, valley, and plain."

Quite so. The hypothesis of the unchanging laws of nature may not only be regarded as the geological postulate, but as the postulate of all science as at present conceived. We are fully justified, too, in assuming, e.g., that the facts summarized by what we call the law of gravitation have been as we know them for a vast period of time. But we can lose nothing by candidly admitting the hypothetical character of even this great postulate of all science, and

[1] "Science and Hebrew Tradition," pp. 134, 135.
[2] Class-Book of Geology, p. 299.

the possibility that new knowledge may ultimately modify the principle as at present held. To keep an open door for all increase of knowledge cannot but aid the cause of scientific progress. Only the survival of dogmatism beyond the conditions that gave it birth and the need of dogmatic teaching in our schools and colleges can account for the continued readiness of some men of science to repeat the old watchword, "It cannot be conceived."

Let me illustrate my meaning by an anecdote. At Takapuna, near Auckland, is a fresh-water lake, nearly at sea-level, regarded by popular theory as the crater of an extinct volcano. Here, one day, discussing the origin of the lake with some Auckland University students, I was asked, "Has the earth's water-envelope been greater or less in past ages? Are we justified in assuming the relative conditions of land and water to have been in the past as they are now? May not both the igneous and the aqueous forces observed by our geologists differ both in degree and kind from the similar forces of a primitive age?" And led on by these questions we soon ventured upon all sorts of heterodoxy, drew imaginary pictures of an evolution of water, of air, of combustion, until we at last came to a conclusion that nature had intended us for the founders of a new science which was to be named "The biology of the elements ancient and modern."

Twelve years have elapsed since our ideal conversation, and physicists need not be reminded of certain signs now visible on the horizon of knowledge which seem to dimly foreshadow the partial realization of our Takapuna dreams. But it is not my present purpose to discuss new physical hypotheses; it is merely to say what I then said to our Auckland students: "There is no finality in any hypothesis or law of science, and for this reason, if for no other, it is the duty of every man of science to plainly state every assumption on which his science rests, and to put these statements not in out-of-the-way corners, but in the very front of his scientific teaching or writing." How much the advance of discovery could be aided by the student's early acquaintance with the hypothetical and provisional character of his principles—by the constant reminder of an open door for new observations and new inferences—none but those who hold exaggerated views of the need of dogmatic teaching for the young will fail to perceive.

The dogmatism of some geological textbooks deserves the more severe censure because there are no textbooks of science more eagerly read by that omnivorous person, 'the general reader'—none, consequently, more likely, if they contain loose thinking, to diffuse unscientific thought under the name of science. For your 'general reader,' be it noted, is almost as intolerant of hypothesis, plainly stated as such, as an ancient Hebrew would have been if his rulers had boldly told him, "These useful changes in your barbarous customs we assume to be the will of a divine Lawgiver, because we know that you will not accept the improvement unless it comes to you through the door of this fiction." But rational faith in hypothesis—i.e. faith ready at any moment to accept new knowledge and

to modify the hypothesis accordingly—is just the essential quality of a truly scientific mind, just the quality that the 'general reader,' with his eternal haste for generalization and his eternal zeal for dogma, can never understand.

> "For such the story of the race—
> Chance oft has found what System lost;
> For System claims too high a place,
> And oft too high a price has cost."

5. There are other directions in which the candid statement of hypotheses can only minister to the real strength and interest of geological science. The various classifications of rocks, for example, lose none of their value by being openly reduced to their true level of tentative work, instead of aping a 'natural' origin. Botanical and zoological systems of classification can lose nothing by the same straightforwardness. But there is another aspect in which the deficiencies of our geological textbooks disclose themselves.

The historical study of geology may not at first sight appear a fruitful field for research. A science comparatively young seems to possess as yet but little history, though this fact should by no means excuse the total absence of any sketch of such history in almost all textbooks of geology. But though geology, under its own name and working by scientific methods, is of such recent origin, geological thinking of some sort is found all over the world and in all the literatures of the world from the earliest times. When, for example, Hebrews described their God as "moulding mountains" or "cleaving the earth with rivers," as "putting forth his hand upon the flint" or "breaking down the rocks," it is clear that the geologists' earth-sculpture was being observed, though very differently explained, by these primitive thinkers.

If it be said that such primitive thinking is not nowadays worth our study, I answer that even our wisest men of science are liable to gross blunders if they neglect such historical work. Professor Huxley, for example, in his "Physiography," not long ago confused the modern theory of atmospheric circulation with the ancient thought of that Hebrew writer who speaks of the rivers "returning to the place from whence they come." The author of "Ecclesiastes," as I have elsewhere proved, was referring to an entirely different kind of water-circulation by which ancient Hebrew thought accounted for the origin of springs as an outlet of their "waters beneath the earth," waters upon which they conceived their earth to rest. If it were for no other purpose than to guard ourselves against a wild confusion of modern with ancient thinking, we must study primitive geology as expressed or implied in the writings of ancient times. A fascinating study, this primitive geology, but needing not only patient research but also large linguistic knowledge. Yet I see no reason why our handbooks of the future should not contain both a brief history of geology as a science and an outline of the beginnings of thought on geological subjects, alike in ancient literatures and in uncivilized peoples now living.

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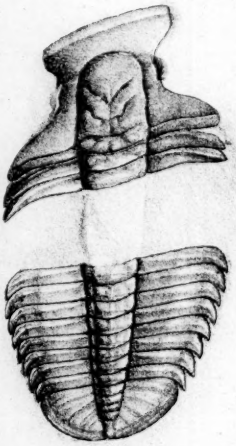

1 x 1½

3 x 2

4 x 2

7

6 x 1½

G.M.Woodward del.et lith. West,Newman imp.

Salter's Undescribed Trilobites *(Part 1.)*

IV.—Woodwardian Museum Notes: Salter's Undescribed Species.

By F. R. Cowper Reed, M.A., F.G.S.

(PLATE XII.)

IN the "Catalogue of the Cambrian and Silurian Fossils in the Woodwardian Museum," compiled by J. W. Salter, F.G.S., and published in 1873, many new specific names occur, in some cases accompanied by a few words of description, but frequently by none at all. Although several of these species have been described by subsequent writers, there yet remains a large number which are only known by their names, some of which have found their way into geological literature. It therefore seemed desirable to rescue these forms from their present unstable position, and to issue a detailed account of their characters to avoid future confusion. The original specimens are in the Woodwardian Museum, and though in many instances they are in a poor state of preservation, rendering the precise and minute diagnosis of the species difficult, yet the subsequent acquisition of further specimens of the same forms has enabled me to make the descriptions more complete.

TRILOBITA.

Olenus (s.g. Parabolinella) Planti, Salter. (Pl. XII, Fig. 1.)

1873. *Olenus Plantii*, Salter: Cat. Camb. Sil. Foss. Woodw. Mus., p. 11 (*a* 272).
1877. *Olenus Plantii*, H. Woodward: Cat. Brit. Foss. Crust., p. 47.
1891. *Olenus Planti*, Woods: Cat. Type Foss. Woodw. Mus., p. 149.

Salter described this species (loc. cit. supra) as follows:—"An oval species, much flattened and expanded. Mr. J. Plant, who discovered it, has distributed casts and photographs of this fine and well-marked fossil." In addition to the almost complete specimen labelled *a*, 272, from the Upper Lingula Flags of Moel Gron, Upper Mawddach, there are two casts and a photograph of the same, and two casts and a photograph also of an imperfect head-shield, showing the free cheek attached, from the same beds at Craig y Dinas. These were presented to the Woodwardian Museum by Mr. Plant. On the specimen *a*, 272 the name "*Conocoryphe Plantii*" is written in white paint, but by whom or at what date is uncertain. From this material the following diagnosis of the species is possible:—

Diagnosis.—General shape oval. Head-shield almost semicircular in outline, the curve being slightly flattened in front; about twice as broad as long. Genal angles spined. Glabella subquadrate, nearly as broad as long, slightly narrowing anteriorly; about three-fourths the total length of the head-shield; gently convex and raised above cheeks, from which it is sharply marked off by straight regular axal furrows which converge a little towards the front end round which they curve and meet, defining it from the flattened pre-glabellar common portion of the fixed cheeks. Surface of glabella marked with two distinct pairs of lateral furrows. The furrows of the posterior pair run obliquely backwards with rather an irregular wavy course at angles of about 45° to the axal furrows,

and unite in the middle at a distance from the neck-furrow equal to the width of the occipital ring, thus forming a broad U-shaped groove across the glabella. The furrows of the anterior pair have a similar wavy backward course parallel to the posterior pair, but they meet in the middle at an acute angle in a broad V instead of U at a point situated at just half the total length of the glabella. The outer ends of both pairs of furrows, particularly of the posterior pair, curve backwards just before reaching the axal furrows, and diminish considerably in strength.

Frontal lobe of glabella subtriangular in shape and large, being just half the length of the glabella. Neck-furrow nearly straight, marking off a rather broad occipital ring of regular width ornamented with a small median tubercle, and divided obscurely into three portions by two faint oblique arched furrows arising from the posterior angles and meeting in the middle on the neck-furrow. Eye rather small, equal in length to the width of the middle glabellar lobe; situated just opposite or a little in front of this lobe, a short distance from the axal furrow and near the front end of the glabella, with which it is connected by a weak 'eye-line.'

Facial sutures cut the front margin of the head-shield at angles of rather more than 60°, and at a distance apart of about one and a half times the width of the glabella. From the point of section each suture takes a backward and inward course in nearly a straight line to the eye, round the projecting lobe of which it sweeps; thence it bends obliquely backwards in a weak outward curve to cut the posterior margin of the head-shield at an angle of about 45° and at a distance from the axal furrow nearly equal to the basal width of the glabella and at about two-thirds the distance to the genal angle.

Border present round the anterior edge of the head-shield, of moderate width and rounded, marked off by a distinct marginal furrow. Neck-ring behind the fixed cheeks about equal in width to this anterior border, but only half the width of the occipital ring.

Free cheeks (shown in the specimen from Craig y Dinas attached to a portion of the middle-shield) roughly triangular in shape, and furnished with a short straight genal spine less than half the length of the head-shield and directed slightly outwards.

Thorax, incompletely known. Only ten segments are preserved in our specimen from Moel Gron, two of these being attached to the head-shield and separated from the rest of the body by a space of 7 mm. in length, which is equal to about five segments. It is clear from an examination of the specimen that this space was originally occupied by segments of the body which are now missing, for the axis of the second segment attached to the head is nearly one and a half times as wide as the axis of the first segment of the detached posterior portion, and the two portions did not therefore fit together. There does not seem to have been any movement or separation of the two portions of the specimen, for if the axial furrows of the anterior part be continued in their course backwards across the gap they are found to exactly meet those of the posterior part and to preserve the regular tapering of the axis. We may therefore conclude that

the thorax was composed of the ten segments which we now see *plus* five segments to fill up the existing gap.

Axis of thorax gently convex, unornamented, and gradually decreasing in width posteriorly. Pleural portions on each side about one and a half times as wide as the axis, but showing posteriorly a slight increase in relative width. Pleuræ straight with parallel margins as far as the distant fulcrum, at which they bend backwards to end in a short broad falcate free point. Each pleura is marked by a strong straight continuous diagonal furrow, curving round at the fulcrum to end at the point.

Pygidium transverse in shape, broadly semicircular, with a regular rounded margin, and with a distinct marginal furrow marking off a narrow border. Axis convex, bluntly pointed, very slightly tapering, composed of four rings; length about two-thirds that of the pygidium, connected with the posterior edge of pygidium by a short, sharply pointed, unsegmented, and less elevated appendix, which interrupts the continuity of the border. On the lateral portions of the pygidium four pairs of pleuræ with their diagonal furrows are present, and of these the anterior pair has the furrows the most strongly marked.

MEASUREMENTS.

	mm.
Length of trilobite	37·0
Length of head-shield	12·0
Width (estimated) of head-shield	25·0
Width of middle-shield at base	19·0
Width of fixed cheek at base	6·0
Length of glabella	8·5
Width of ditto at base	7·0
Length of pygidium	5·0
Width of ditto	12·5

REMARKS.—The subgenus of *Olenus* to which this species appears to belong is that named *Parabolinella* by Brögger.[1] The subquadrate glabella not reaching the front margin, the wide preglabellar portion of the head-shield, the rounded margin, the course of the facial suture, the position and relative size of the eyes, the characters of the occipital ring, the genal spines of the free cheeks, the pygidium with regular bordered edge, not furnished with spines, with a 3–4 jointed axis, and lateral lobes marked with distinct furrows, are the most important features in common between *O. Planti* and the subgenus *Parabolinella* as defined by Brögger. The presence of only two instead of three lateral furrows on the glabella is a point of difference, but perhaps not of much importance in this case, as we see on examining Brögger's figure of *P. rugosa* (loc. cit., tab. iii, f. 3) that an indefinite number of furrows seem to be present in that species, and their irregular character and tendency to unite in the middle also reminds us of *O. Planti*. In the case of the pleuræ their shape and straight diagonal furrow resemble more closely those of *Parabolina spinulosa*, but the short

[1] Die Silur. Etag., 2 and 3 (1882), p. 102, tab. iii, f. 2*a*, *b*, 3, and 4*a*.

falcate instead of long spinose ends distinguish them. Moreover, the characters of the pygidium and head-shield completely separate *O. Planti* from the subgenus *Parabolina*.

The only other British forms calling for any comparison are the so-called '*Conocoryphe*' *Williamsoni* (Belt),[1] the species of *Parabolinella* described by Miss Crosfield and Miss Skeat,[2] and *Olenus triarthrus* (Callaway) from the Shineton Shales. Belt's species probably belongs to *Parabolinella*, the only important point of difference being the presence of two instead of three pairs of glabellar furrows. The pygidium of '*Conocoryphe*' *Williamsoni* seems to be almost identical with that of *O. Planti*, and the pleuræ are very similar, but the characters of the glabella and head-shield are sufficient to warrant their specific separation.

The species of *Parabolinella* from the Tremadoc of Nant y Glasdwr, described by Miss Crosfield and Miss Skeat (loc. cit.), is only known by an imperfect head-shield. It differs from *O. Planti* by the greater number of glabellar furrows, by the larger eyes, by the course of the facial sutures, and by the narrower fixed cheeks.

The only other British species of *Parabolinella* is *P.* [*Olenus*] *triarthrus* (Callaway),[3] from the Shineton Shales, and it differs from *P. Planti* by its broader glabella, by the union of the posterior and anterior pairs of glabellar furrows, by the tubercles on the axial rings of the thorax, and by the characters of the pygidium. But it is evidently a closely allied species.

OLENUS (CTENOPYGE?) EXPANSUS, Salter. (Pl. XII, Figs. 2 and 3.)

1873. *Olenus* (*Sphærophthalmus*) *expansus*, n.sp., Salter: Cat. Camb. Silur. Foss. Woodw. Mus., p. 12 (*a* 275).
1877. *Olenus* (*Sphærophthalmus*) *expansus*, Woodward: Cat. Brit. Foss. Crust., p. 47.
1891. *Olenus* (*Sphærophthalmus*) *expansus*, Woods: Cat. Type Foss. Woodw. Mus., p. 149.

The two specimens on which Salter founded this species are exceedingly imperfect and fragmentary, and consist only of a few broken thoracic rings attached in one case to a portion of a pygidium showing the margin. This specimen, though crushed and flattened out, is the less incomplete of the two, but is extremely unsatisfactory for a specific description. Salter (loc. cit. supra) describes the species thus: "A very narrow axis and enormously wide flanks distinguish this." The long narrow pleuræ, of which 7–8 are visible in the better and larger specimen and 7 in the smaller one, are straight, with parallel sides, extend at right angles to the axis, and bend sharply close to the ends to terminate in short points, not projecting outwards nor produced into spines. Each pleura is apparently furnished with a narrow raised rounded ridge running along its anterior margin, with a distinct groove behind it. The general

[1] GEOL. MAG., Dec. I, Vol. V (1868), p. 5, Pl. II, Figs. 7–11. Salter's *Conocoryphe Williamsoni* (Cat. Camb. Sil. Foss. Woodw. Mus., p. 12) is distinct from Belt's form.

[2] Q.J.G.S., vol. lii (1896), p. 537, pl. xxvi, figs. 11 and 12.

[3] Callaway: Q.J.G.S., vol. xxxiii (1877), p. 666, pl. xxiv, fig. 6. Brögger: Nyt Magazin für Naturvidenskaberne, vol. xxxvi (1897), pp. 179–185, 200.

surface of the pleura bears no furrow or ridge, but close to the posterior margin are two equal raised thread-like lines parallel to the margin and to each other and separated by a narrow groove.

The axis of the thorax is very narrow relatively to the pleuræ; it is cylindrical as in *Ctenopyge pecten* (Salter), not tapering at all posteriorly, so far as is seen in the smaller specimen. In the larger specimen the axis is too imperfectly preserved to make out any feature clearly. The pygidium, according to the latter specimen, appears to be broadly parabolic and slightly pointed or apiculate posteriorly, but this appearance may be due to distortion and crushing. Its lateral lobes are flat and marked by straight pleuræ similar to those of the thorax, and like them distinctly furnished with the ridge and thread-like lines. They terminate on the margin in free ends, bluntly pointed and backwardly directed, of which six or seven are distinguishable. The axis of the pygidium is not preserved.

It is extremely doubtful to what subgenus or even genus this imperfect fossil should be ascribed. It however seems more allied to *Eurycare* or *Ctenopyge* than to *Sphærophthalmus*. The long, straight spinose pleuræ of the thorax, the narrow axis, the numerous segments of the pygidium, with the free pointed terminations of the pleuræ on its margin, resemble *Ctenopyge*, but the shorter length of these spines and their falcate shape distinguish them. It is not, however, possible to fix with certainty the true generic position of this imperfectly known species.

The specimens (*a*, 275 of Salter's Catalogue) were found in the Upper Lingula Flags of Moel Gron.

	mm.
Length of pygidium of larger specimen ...	12·0
Width of ditto	23·0
Width of thorax	25·0
Width of axis of thorax	4·0

N.B. These measurements are only approximate, owing to the bad state of preservation of the specimen, and its distortion.

Neseuretus recurvatus (Hicks)? (Pl. XII, Fig. 4.)

1873. *Calymene vexata*, Salter: Cat. Camb. Sil. Foss. Woodw. Mus., p. 22 (*a* 469).
1888. *Calymene vexata*, Etheridge: Pal. Foss. Brit. Isl., p. 46.
1891. *Neseuretus*, sp., Woods: Cat. Type Foss. Woodw. Mus., p. 148.

The small pygidium named by Salter *Calymene vexata* occurs on a slab with *Niobe* [*Asaphellus*, Brögger] *menapiensis*, *Neseuretus quadratus*, *Ctenodonta menapiensis*, and *Ctenodonta cambriensis* from the Tremadoc Beds (=Arenig, according to Salter) of Ramsey Island. The species is somewhat doubtful, but the pygidium appears to resemble that of *Neseuretus recurvatus* (Hicks).[1]

Neseuretus quadratus (Hicks)? (Pl. XII, Fig. 5.)

1873. *Calymene ultima*, Salter: Cat. Camb. Sil. Foss. Woodw. Mus., p. 22 (*a* 469).
1888. *Calymene ultima*, Etheridge: Pal. Foss. Brit. Isl., p. 46.
1891. *Calymene ultima*, Woods: Cat. Type Foss. Woodw. Mus., p. 141. (Specimen supposed to be lost.)

The slab of rock on which Salter's *Calymene vexata* occurs also contains his original specimen of *Calymene ultima*. It consists of

[1] Hicks: Q.J.G.S., vol. xxix (1872), p. 45, pl. iii, figs. 5, 6.

a good head-shield only slightly distorted, and corresponds in character to *Neseuretus quadratus* (Hicks),[1] but apparently belongs to a young individual, as it is of comparatively small size (13 mm. long). The glabella is too narrow to ascribe it to *N. ramseyensis*, Hicks. The basal lobes are well shown, and there is a faint indication of the two anterior pairs of lateral furrows. The punctation of the surface also corresponds to that of *N. quadratus*.

NESEURETUS, sp. (Pl. XII, Fig. 6.)

1873. *Homalonotus monstrator*, Salter: Cat. Camb. Sil. Foss. Woodw. Mus., p. 22 (*a* 482).
1888. *Homalonotus monstrator*, Etheridge: Pal. Foss. Brit. Isl., p. 54.
1891. *Neseuretus*, sp., Woods: Cat. Type Foss. Woodw. Mus., p. 148.

Salter gave the name *Homalonotus monstrator* to a trilobite from what he considered the base of the Arenig Beds (=Tremadoc, according to Hicks) in Ramsey Island. The single original specimen (*a* 482) on which this species was founded consists of an imperfect and badly-preserved pygidium, which obviously belongs to the genus *Neseuretus*,[2] though the species is indeterminable.

EXPLANATION OF PLATE XII.

[All the figures are of Salter's original specimens in the Woodwardian Museum.]

FIG. 1.—*Olenus* (*Parabolinella*) *Planti*, Salter. Upper Lingula Flags, Moel Gron. *a*, 272.
FIGS. 2 and 3.—*Olenus* (s.g. ?) *expansus*, Salter. Upper Lingula Flags, Moel Gron. *a*, 275.
FIG. 4.—*Neseuretus recurvatus*, Hicks? Tremadoc, Ramsey Island. *a*, 469.
FIG. 5.—*Neseuretus quadratus*, Hicks? Tremadoc, Ramsey Island. *a*, 469.
FIG. 6.—*Neseuretus*, sp. Tremadoc, Ramsey Island. *a*, 482.

V.—TERTIARY FORAMINIFERAL LIMESTONES FROM SINAI.

By FREDERICK CHAPMAN, A.L.S., F.R.M.S.

(PLATES XIII AND XIV.)[3]

THE following descriptions are based upon a collection of foraminiferal limestones, chiefly nummulitic, from Sinai, which were sent to the British Museum for description and determination by Captain H. G. Lyons, R.E., F.G.S., Director of the Geological Survey of Egypt.

Our previous knowledge of Sinaitic foraminifera has been somewhat scanty. It was pointed out, however, chiefly by Bauerman, that the Nummulitic Series is very well developed in this particular area, the country on the east side of the Gulf of Suez.

The occurrence of *Nummulites* and *Operculina* is recorded in Mr. Bauerman's paper[4] mainly from a locality south of Wadi Gharandel. Professor Rupert Jones supplied a note to that paper, and from the latter locality recorded *Nummulites Gizehensis* (large

[1] Hicks: Q.J.G.S., vol. xxix (1872), p. 45, pl. iii, figs. 11–13.
[2] Hicks: Q.J.G.S., vol. xxix (1872), p. 44.
[3] The Plates will appear with Part II, in the August Number.
[4] "Note on a Geological Reconnaissance made in Arabia Petræa in the Spring of 1868": Quart. Journ. Geol. Soc., vol. xxv (1868), p. 38.

and small), ***N. Ramondi***, ***N. curvispira***, and ***N. intermedia***; whilst from "the lowest rock seen just beyond Pharaoh's Fall" he records remains of *Nummulites Ramondi* and *Operculina canalifera* (?).

Foraminifera have been recorded from Sinai also by Ehrenberg.[1] These were principally obtained from washings of the rocks, and consequently are exceptionally minute forms.

Other occurrences of foraminifera from the adjacent country, chiefly Palestine, are noted by Fraas,[2] who described a form under the name of *Nummulites cretacea* from the Hippurite Limestone near Jerusalem, and which from the figure given is certainly not a nummulite, but bears some resemblance to a turgid *Orbitoides*, and is most probably of Tertiary age.[3] The same author mentions two other species, *Nummulites variolaria* and *N. Arabiensis*.

Lartet has figured and noted three species of *Nummulites* from Wadi Gharandel,[4] namely, ***N. Lyelli***, ***N. Guettardi***, and ***N. Lucasana***.

Lastly, a series of specimens collected by the Palestine Exploring Expedition in 1865 from Gerizhem have been identified by Professor T. Rupert Jones,[5] who enumerates ten species, and some of these are comparable with our Sinaitic specimens.

The specimens dealt with in this paper were collected by Mr. Barron, of the Egyptian Geological Survey, between January and June, 1899.

The following is an epitomized account of the rock-specimens, with their contents :—

No. 4,111, 1*l*.—"Foraminiferal limestone; top of Jebel Abyad, south of Wadi Gharandel, Sinai." Mokattam Series (Middle Eocene).

A dense cream-coloured limestone, largely composed of ***Nummulites subdiscorbina*** and ***N. curvispira***, associated with a fair number of ***N. Gizehensis***, var. ***Pachoi***. The nummulites in these rock-specimens lie massed together, forming a kind of bank, which is in turn covered with fine detrital mud containing smaller foraminifera, such as *Bolivina*, *Globigerina*, *Discorbina*, and *Rotalia*. One of the nummulites in this rock has been partially transformed into beekite.

The genera and species found in these rock-specimens are:—*Bolivina punctata*?, d'Orbigny; *Globigerina bulloides*, d'Orb.; *G. conglobata*, Brady; *G. cretacea*?, d'Orb.; *Discorbina rugosa* (d'Orb.); *D. globularis* (d'Orb.); *Rotalia calcariformis* (Schwager); *Nummulites subdiscorbina*, De la Harpe; *N. curvispira*, Meneghini; *N. Gizehensis*, Ehr., var. *Pachoi*, De la Harpe; *Orbitoides dispansa* (Sow.); *O. ephippium* (Schlotheim); and *O. papyracea* (Boubée).

No. 4,112, 2*l*.—"Foraminiferal limestone, beach deposit (later);[6]

[1] Mikrogeologie, vol. ii (1854), pl. xxv c. Also Parker & Jones: Ann. Mag. Nat. Hist., vol. ix (1872), p. 289.

[2] Aus dem Orient, 1867, pp. 82–4, pl. i, figs. 8*a–c*.

[3] See also Lartet: "Explor. géol. Mer Morte," 1877, pp. 157–9.

[4] Lartet, "Essai sur la Géol. Palestine," pt. ii, Paléontologie: Ann. Sci. géol., vol. iii (1872), p. 89, pl. ix, figs. 23, 25, 26.

[5] Catal. Foss. Foram. Brit. Mus., 1882, p. 49.

[6] Mr. Barron writes (March, 1900) with regard to this deposit: "It has the characters of a beach deposit in that it is gritty and contains well-marked conglomerate beds. There is no doubt, however, that it is part of the Eocene series."

Jebel Abyad, Sinai." ? Bartonian (Upper Eocene) or ? top of Mokattam Series (Middle Eocene).

A soft-textured, pale cream-coloured rock. Thin sections of this specimen when viewed under the microscope show the rock to be finely granular to crystalline, and to contain a fair number of foraminifera, some of which are broken and worn (? derived).

The foraminifera in this rock are :—*Globigerina bulloides*, d'Orb.; *Operculina complanata* (Defr.), var. *discoidea*, Schwager; *Nummulites planulata* (Lamarck); *N. variolaria* (Lam.); and *Orbitoides dispansa* (Sowerby).

Nos. 4,135, 3*l*, and **4,113**, 4*l*.—"Foraminiferal limestone; junction of Wadi Baba and Wadi Shellál." Libyan Series (Lower Eocene).

This rock has a whitish chalky appearance, and is seen under the microscope to be almost completely recrystallized as dolomite, the rhomb-sections of that mineral being very perfect. The foraminifera have retained generally their shape and structure, but in many instances their tests are bitten up by dolomite rhombs. The chambers of the foraminifera are also often filled up by the crystals. Besides foraminifera numerous fragments of polyzoa (unaltered) are scattered throughout the rock.

The foraminifera seen in these specimens are :—*Textularia agglutinans*, d'Orb.; *Operculina complanata* (Defr.), var. *canalifera*, d'Archiac; and *Nummulites Ramondi*, Defr.

No. 4,163, 5*l*.—"Nummulites near top of Jebel Safariat, Sinai." Mokattam Series (Middle Eocene).

A collection of nummulites of the type *N. complanata*, comprising *N. Gizehensis* (Forskål), var. *Ehrenbergi*, De la Harpe; *N. Gizehensis*, var. *Lyelli*, d'Archiac & Haime; and *N. Gizehensis*, var. *Pachoi*, De la Harpe.

No. 3,598, 13*l*.—"Nummulitic bed, Wadi Khadáhid, Sinai." Mokattam Series (Middle Eocene).

An ochreous-coloured, incoherent limestone, consisting almost entirely of nummulites (chiefly *N. curvispira*).

The following foraminifera were found :—*Truncatulina umbonifera* (Schwager); *Nummulites Gizehensis*, var. *Pachoi*, De la Harpe; *N. curvispira*, Meneghini; *N. Barroni*, sp. nov.; and *N. Ramondi*?, Defrance.

No. 3,902, 15*l*.—"Foraminiferal limestone, Jebel Krer (same range as Jebel Abyad), Sinai." Libyan Series (Lower Eocene).

An impure chalky limestone, with many included fragments of an older rock, possibly Cretaceous in age, which includes *Globigerina cretacea*?, d'Orb. When viewed microscopically, this limestone appears to have originally been a fine-grained calcareous mud, with numerous specimens of foraminifera. We find here *Miliolina circularis* (Born.); *Alveolina Boscii* (Defr.); *A. decipiens*, Schwager; *Bigenerina*? *nodosaria*, d'Orb.; *Globigerina cretacea*?, d'Orb.; *Operculina complanata* (Defr.), var. *canaliculata*, d'Archiac; *Nummulites Guettardi*, d'Arch. & Haime, var. *antiqua*, De la Harpe; *Orbitoides dispansa* (Sow.); and *O. papyracea* (Boubée).

In the following descriptions, especially with regard to the nummulites, I have had the advantage of consulting Professor T. Rupert Jones, F.R.S., to whom I am much indebted.

FORAMINIFERA.

Family MILIOLIDÆ.

Subfamily MILIOLININÆ.

MILIOLINA, Williamson [1858].

Miliolina circularis (Bornemann). (Pl. XIV, Fig. 1.)

Triloculina circularis, Bornemann, 1855: Zeitsch. deutsch. Geol. Gesell., vol. vii, p. 349, pl. xix, fig. 4.
Miliolina circularis (Born.), Sherborn & Chapman, 1886: Journ. Roy. Micro. Soc., ser. II, vol. vi, p. 742, pl. xiv, figs. 2*a*, *b*.

A *Miliolina* occurs in a section of one of the Sinai limestones. It perfectly agrees in outline and the disposition of the inner chambers with the above species, especially those found in Tertiary clays elsewhere, as the London Clay and the Septarian Clay of Hermsdorf.

Coll. Geol. Surv. Egypt, No. 3,902, Box No. 15*l*. Libyan Series (Lower Eocene): Jebel Krer, Sinai.

Subfamily ALVEOLININÆ.

ALVEOLINA, d'Orbigny [1826].

Alveolina Boscii (Defrance). (Pl. XIII, Fig. 6*a*.)

Oryzaria Boscii, Defrance, 1820: Dict. Sci. Nat., vol. xvi, p. 106; Atlas Zooph., pl. xlviii, fig. 4.
Alveolina Boscii (Defr.), d'Orb., 1826: Ann. Sci. Nat., vol. vii, p. 306, No. 5; Modèles, No. 50. Brady, 1884: Rep. Chall., vol. ix, p. 222, pl. xvii, figs. 7–12.

The elongate and more or less fusiform specimens of *Alveolina* in the oldest Tertiary limestones of Sinai may be referred to the above species. Schwager figures an allied form, *A. frumentiformis*,[1] which is more slender than *A. Boscii*, from the Egyptian limestone of the Libyan Series.

Coll. Geol. Surv. Egypt, No. 3,902, Box No. 15*l*. Libyan Series (Lower Eocene): Jebel Krer, Sinai. Rare.

Alveolina (*Flosculina*) *decipiens*, Schwager. (Pl. XIV, Fig. 2.)

Alveolina (*Flosculina*) *decipiens*, Schwager, 1883: Palæontographica, vol. xxx, Pal. Theil, p. 103, pl. xxvi (iii), figs. 1*a*–*k*.

This interesting species appears to be similar to some *Alveolinæ* from India, associated in like manner with *Nummulites* and *Orbitoides*. It was found by Schwager in the Libyan Series of Nekeb-el-Farudj and El-Guss-Abu-Said.

Coll. Geol. Surv. Egypt, No. 3,902, Box No. 15*l*. Libyan Series (Lower Eocene): Jebel Krer, Sinai. Frequent.

[1] Palæontographica, vol. xxx (1883), Pal. Theil, p. 100, pl. xxv (ii), figs. 4*a*–*i*.

Family TEXTULARIIDÆ.

Subfamily TEXTULARIINÆ.

TEXTULARIA, Defrance [1824].

Textularia agglutinans, d'Orbigny. (Pl. XIV, Fig. 3.)

Textularia agglutinans, d'Orb., 1839: Foram. Cuba, p. 144, pl. i, figs. 17, 18, 32–34.

A specimen of the above was met with in one of the sections, which has the aboral end somewhat more attenuate than is usual in the typical form. The texture of the shell-wall is coarsely arenaceous, and the limestone in which it occurs was probably deposited in quite shallow water.

Coll. Geol. Surv. Egypt, No. 4,113, Box No. 4*l*. Libyan Series (Lower Eocene): junction of Wadi Baba and Wadi Shellál.

BIGENERINA, d'Orbigny [1826].

Bigenerina nodosaria ?, d'Orbigny. (Pl. XIII, Fig. 7*b*.)

Bigenerina nodosaria, d'Orb., 1826: Ann. Sci. Nat., vol. vii, p. 261, No. 1, pl. xi, figs. 9–11; Modèles, No. 57.

Dimorphina nodosaria, d'Orb., 1846: Foram. Foss. Vienne, p. 221, pl. xii, figs. 21, 22.

Bigenerina nodosaria, d'Orb., Brady, 1884: Rep. Chall., vol. ix, p. 369, pl. xliv, figs. 14–18.

A vertical section of a stout bigenerine form occurs in one of the sections, and is most probably referable to the above species. *B. nodosaria* has been recorded from various deposits dating from Middle Tertiary times.

Coll. Geol. Surv. Egypt, No. 3,902, Box No. 15*l*. Libyan Series (Lower Eocene): Jebel Krer, Sinai.

Subfamily BULIMININÆ.

BOLIVINA, d'Orbigny [1839].

Bolivina punctata ?, d'Orbigny. (Pl. XIV, Fig. 4.)

Bolivina punctata, d'Orb., 1839: Voyage Amér. Mérid., vol. v, Foraminifères, p. 63, pl. viii, figs. 10–12.

B. phyllodes (Ehrenberg), Schwager, 1883: Palæontographica, vol. xxx, Pal. Theil, p. 113, pl. xxix (vi), fig. 10.

The specimen under notice is a vertical section of a narrow form cut at such an angle as to give a chevroned aspect to the chambers. It is possibly referable to the well-known Tertiary species *Bolivina punctata*, and similar specimens have occurred in both the Libyan and Mokattam Series of Egypt.

Coll. Geol. Surv. Egypt, No. 4,111, Box No. 1*l*. Mokattam Series (Middle Eocene): top of Jebel Abyad, south of Wadi Gharandel, Sinai.

Family GLOBIGERINIDÆ.

GLOBIGERINA, d'Orbigny [1826].

Globigerina bulloides, d'Orbigny. (Pl. XIV, Fig. 5.)

Globigerina bulloides, d'Orb., 1826: Ann. Sci. Nat., vol. vii, p. 277, No. 1; Modèles, No. 76. Schwager, 1883: Palæontographica, vol. xxx, Pal. Theil, p. 118, pl. xxvii (iv), figs. 5*a–c*.

Several undoubted specimens of this form were detected in the fine material of the sections made from rock-specimen No. 4,112.

Schwager found *G. bulloides* in both the Libyan and the Mokattam Series in Egypt.

Coll. Geol. Surv. Egypt, No. 4,112, Box No. 2*l*. Bartonian Series (Upper Eocene) or top of Mokattam Series (Middle Eocene) : Jebel Abyad, Sinai.

Globigerina conglobata, Brady. (Pl. XIV, Fig. 6.)

Globigerina conglobata, Brady, 1879 : Quart. Journ. Micro. Sci., vol. xix, p. 72. Id., 1884 : Rep. Chall., vol. ix, p. 603, pl. lxxx, figs. 1–5 ; pl. lxxxii, fig. 5.

This species is occasionally seen in the sections of No. 4,111, but the specimens are somewhat fragmentary. It has previously occurred in beds as old as the Oligocene or Miocene, notably in the limestones of Christmas Island. It is distinguished by the fewness of the chambers and the comparative thickness of the shell-walls.

Coll. Geol. Surv. Egypt, No. 4,111, Box No. 1*l*. Mokattam Series (Middle Eocene) : top of Jebel Abyad, south of Wadi Gharandel, Sinai.

Globigerina cretacea ?, d'Orbigny. (Pl. XIV, Fig. 7.)

Globigerina cretacea, d'Orb., 1840 : Mém. Soc. géol. France, ser. 1, vol. iv, p. 34, pl. iii, figs. 12–14.

G. cf. *cretacea*, d'Orb., Schwager, 1883 : Palæontographica, vol. xxx, Pal. Theil, p. 119, pl. xxix, figs. 13*a–d*.

Numerous small specimens of a small-chambered, neatly coiled *Globigerina*, very closely resembling *G. cretacea*, occur in the presumably oldest nummulitic beds of Sinai. This species has also been doubtfully referred to as occurring in the argillaceous beds (Libyan Series) of El-Guss-Abu-Said by Schwager.

It is of great interest to note this occurrence here, since if the species be proved by specimens isolated from the rock, they will either have been derived from neighbouring Cretaceous beds or otherwise show an upward range for the species, typical examples of which are not known out of the Cretaceous formations.

Coll. Geol. Surv. Egypt, No. 4,111, Box No. 1*l*. Mokattam Series (Middle Eocene) : top of Jebel Abyad, south of Wadi Gharandel, Sinai. Also No. 3,902, Box No. 15*l*. Libyan Series (Lower Eocene : Jebel Krer (same range as Jebel Abyad), Sinai.

Family ROTALIIDÆ.

Subfamily ROTALIINÆ.

DISCORBINA, Parker & Jones [1862].

Discorbina rugosa (d'Orbigny). (Pl. XIV, Fig. 9.)

Rosalina rugosa, d'Orb., 1839 : Voyage Amér. Mérid., vol. v, pt. 5, Foraminifères, p. 42, pl. ii, figs. 12–14.

Discorbina rugosa (d'Orb.), Brady, 1884 : Rep. Chall., vol. ix, p. 652, pl. lxxxvii, figs. 1, 4. Sherborn & Chapman, 1889 : Journ. Roy. Micro. Sci., p. 487, pl. xi, fig. 33.

This neat little shallow-water organism is fairly well known in Eocene strata, and is a characteristic form in the London Clay.

Coll. Geol. Surv. Egypt, No. 4,111, Box No. 1*l*. Mokattam Series (Middle Eocene): top of Jebel Abyad, south of Wadi Gharandel, Sinai.

Discorbina globularis (d'Orbigny). (Pl. XIV, Fig. 8.)

Rosalina globularis, d'Orb., 1826: Ann. Sci. Nat., vol. vii, p. 271, No. 1, pl. xiii, figs. 1–4; Modèles, 1826, No. 69.

Discorbina globularis (d'Orb.), 1897, Jones & Chapman, in Professor Judd's Second Report on specimens of the deposits of the Nile Delta: Proc. Roy. Soc., vol. lxi, p. 38.

The specimen seen in section is that of a simple, strongly inflated *Discorbina*, similar to the above-named species. It has already been recorded from slices of Eocene pebbles from the Nile Delta, and it is also known from the Eocene of Grignon. It occurs in nearly all fossiliferous strata dating from Tertiary times to the present. In recent deposits *D. globularis* is most abundant in shallow water, averaging about 50 fathoms.

Coll. Geol. Surv. Egypt, No. 4,111, Box No. 1*l*. Mokattam Series (Middle Eocene): top of Jebel Abyad, south of Wadi Gharandel, Sinai.

Truncatulina, d'Orbigny [1826].

Truncatulina umbonifera (Schwager). (Pl. XIV, Figs. 10*a*, *b*.)

Discorbina umbonifera, Schwager, 1883: Palæontographica, vol. xxx, Pal. Theil, p. 126, pl. xxvii (iv), figs. 14*a–d*.

The specimen obtained from the limestone of Sinai is apparently a depauperated or irregularly grown individual of the above species. The affinities of the original specimens and also of the present appear to be nearer *Truncatulina* than *Discorbina*. Schwager's specimens came from the Libyan Series of El-Guss-Abu-Said, Egypt.

Coll. Geol. Surv. Egypt, No. 3,598, Box No. 13*l*. Mokattam Series (Middle Eocene): Wadi Khadáhid, Sinai.

Rotalia, Lamarck [1804].

Rotalia calcariformis (Schwager). (Pl. XIV, Fig. 11.)

Discorbina calcariformis, Schwager, 1883: Palæontographica, vol. xxx, Pal. Theil, p. 120, pl. xxvii, figs. 9*a–d*.

The specimens seen in these sections show a true rotaliform structure in the shell-wall, with an interseptal canal system. Schwager's figures also show secondary shell-thickening, and we therefore refer them to the genus *Rotalia*. *R. calcariformis* is not far removed in outline from *R. calcar* of the present day, but since the latter species shows a marked tendency to vary in the direction of the elongation of the cuspid processes on the outer segments, and *R. calcariformis* has a somewhat blunt cusp, the two series of specimens may reasonably be kept distinct.

R. calcariformis was found in the argillaceous beds of El-Guss-Abu-Said (Libyan Series), Egypt.

Coll. Geol. Surv. Egypt, No. 4,111, Box No. 1*l*. Mokattam Series (Middle Eocene): top of Jebel Abyad, south of Wadi Gharandel, Sinai. Frequent.

Family NUMMULINIDÆ.

Subfamily NUMMULITINÆ.

Operculina, d'Orbigny [1826].

Operculina complanata (Defrance), var. *canalifera*, d'Archiac.
(Pl. XIII, Figs. 3*a*, 4*a*; Pl. XIV, Fig. 12.)

Operculina ammonea, Leymerie (pars), 1844 : Mém. Soc. géol. France, ser. II, vol. i, p. 359, pl. xiii, fig. 11.

O. canalifera, d'Archiac, 1850 : Hist. Prog. Géol., vol. iii, p. 245. D'Archiac & Haime, 1853 : Descr. Anim. groupe nummulitique Inde, p. 182, pl. xii, figs. 1*a–c* ; and vol. ii (1854), p. 346, pl. xxxv, fig. 6*a* ; pl. xxxvi, figs. 15*a*, 16*a*.

O. libyca, Schwager, 1883 : Palæontographica, vol. xxx, Pal. Theil, p. 142, pl. xxix (vi), figs. 2*a–g*.

After a careful comparison of the various specimens of the large and compressed forms of *Operculina* which are often so abundant in the nummulitic series and subsequent formations of Asia, Africa, Europe, and the West Indies, we have arrived at the conclusion that the so-called species, so numerously described and figured, can only be regarded as varieties of the type form *O. complanata* (Defrance). These varieties, nevertheless, when confined within certain limits of characters, determined probably by the influence of local conditions, will prove of value in determining facies and minor series of strata in given areas.

O. complanata, var. *canalifera* is characterized by the rapid increase in the width of the whorls in the last turn or so. The surface of the central area of each chamber is slightly excavate, and the sutural lines of the segments are often marked out by a thick secondary shell growth. Greatest length of test in the specimens from Sinai, $\frac{8}{5}$ inch (10 mm.) ; diameter at oral extremity, $\frac{7}{25}$ inch (7 mm.) ; thickness, $\frac{1}{50}$ inch (·5 mm.).

The original specimens, described by d'Archiac, were from the yellow limestone, Hala range, province of Cutch, India, where it was associated with *Nummulites Ramondi*. *O. complanata*, var. *canalifera*, has also been recorded from the nummulitic beds of Beni Hassan and Cairo, Egypt, and from Palestine and Bulgaria. Described under the name of *O. libyca* by Schwager, and recorded by him from the Libyan Series of El-Guss-Abu-Said.

Coll. Geol. Surv. Egypt, Nos. 4,113 and 4,135, Box Nos. 4*l* and 3*l* respectively. Libyan Series (Lower Eocene) : junction of Wadi Baba and Wadi Shellál, Sinai. Abundant and typical. Also No. 3,902, Box No. 15*l*. Libyan Series (Lower Eocene) : Jebel Krer, Sinai. Frequent, but somewhat dwarfed specimens.

Operculina complanata (Defrance), var. *discoidea*, Schwager.
(Pl. XIV, Fig. 13.)

Operculina discoidea, Schwager, 1883 : Palæontographica, vol. xxx, Pal. Theil, p. 145, pl. xxix (vi), figs. 5*a–d*.

O. cf. *canalifera*, d'Arch., id., 1883 : ibid., p. 144, pl. xxix (vi), figs. 3*a*, *b*.

This variety is distinguished from the foregoing by the even width of the whorls of the shell, which increase but slightly in each turn of the series.

Gümbel has figured a somewhat similar variety from the nummulitic series of Kressenberg, Bavaria, which he has referred to d'Archiac's *Operculina canalifera*.[1]

The specimens from Sinai measure $\frac{7}{25}$ inch (7 mm.) in the diameter of the shell, and its thickness is $\frac{1}{50}$ inch (·5 mm.).

Schwager's specimens were obtained from the white clay of Aradj (Mokattam Series), Egypt.

Coll. Geol. Surv. Egypt, No. 4,112, Box No. 2*l*. ? Bartonian Series (Upper Eocene) or ? top of Mokattam Series (Middle Eocene): beach deposit, Jebel Abyad, Sinai. Common.

HETEROSTEGINA, d'Orbigny [1826].

Heterostegina depressa, d'Orbigny. (Pl. XIII, Fig. 7*a*.)

Heterostegina depressa, d'Orb., 1826: Ann. Sci. Nat., vol. vii, p. 305, No. 2, pl. xvii, figs. 5–7; Modèles, No. 99.

The specimens now under description are very distinctly coiled at the commencement, and in general aspect resemble those specimens which belong to the microspheric form; and which are rare in our modern marine dredgings. This species is more commonly found in the later Tertiaries, but it is not entirely absent from the base of the Eocene.

Coll. Geol. Surv. Egypt, No. 3,902, Box No. 15*l*. Libyan Series (Lower Eocene): Jebel Krer, Sinai. Rare.

(*To be continued in our next Number.*)

VI.—The Development of Brown Mica from Augite by Reaction with Felspathic Material.

By James Parsons, B.Sc. (Lond.).

THE conversion of augite or hornblende into brown mica appears to take place from three causes:—

1. By crushing of pyroxenic minerals and felspar, as has been observed by Professor Bonney in sundry schists of the Alps.[2]

2. By the intrusion of felspathic material into a rock containing augite or hornblende, as in the Harz, where granite invades diabase, converting the augite into biotite.[3] A similar change has been observed in the gabbro of the Barnavave Mountain, in the Carlingford district, the diallage being wholly or in part replaced by biotite owing to the invasion of granophyric magma.[4] In Sark the intrusion of an aplitic magma into almost pure hornblende has resulted in the formation of biotite.[5]

3. By the corrosive action of a residual felspathic magma on previously consolidated augitic constituents. This method of formation has been noted by Mr. T. H. Holland in the augite-diorites

[1] Abhandl. bayer. Akad. Wiss., vol. x (1868), 1870, p. 664, pl. ii, figs. 112*a*, *b*.
[2] Q.J.G.S., vol. xlix, p. 104.
[3] K. A. Lossen: Congrès Internat. Géol. Comptes Rendues de la 4me session, 1888, p. 184.
[4] Sollas: Trans. Roy. Irish Acad., vol. xxx (1894), p. 477.
[5] Bonney: Q.J.G.S., vol. xlviii, p. 122 et seq.

of Southern India. In this instance, after augite and plagioclase had consolidated a hydrous magma was left, which ultimately solidified as micropegmatite; this magma acted readily on the augite, converting it into biotite.[1] Under this head the following observations on some Norwegian rocks should probably be classed.[2]

(1) A granite from Almäs shows a similar process of change to that observed in the above-mentioned augite-diorites. The principal constituents of the rock are, oligoclase, orthoclase, augite of the pale-green non-aluminous type (sahlite), which commonly occurs in granite, biotite, and sphene. The biotite is developed round the augite, which is much corroded, passing into it along its cleavage cracks, in such a way that, in many cases, the line of division is fixed with difficulty. The two minerals are curiously intergrown, but not in such a way as to suggest simultaneous crystallization, for while the biotite invades the augite from the outside it does not form isolated inclusions in the latter. The quartz and orthoclase occur as a mosaic of varying coarseness and of later date than the oligoclase, and locally form patches of micropegmatite. The mosaic extends in narrow seams between the oligoclase crystals, broadening out at their angles to fill the intercrystalline spaces. It is largely developed round the augite-biotite aggregate, the grains separating the flakes of biotite at the margins of the main masses. Appearances suggest that the magma, from which the quartz and orthoclase formed, effected the corrosion of the augite and subsequent development of the biotite in the manner suggested by Mr. Holland. The sphenes occur as idiomorphic crystals, and are the earliest constituents of the rock, for they are included in the augite, which is itself earlier than the oligoclase. Where present in the biotite or in its immediate neighbourhood they are much corroded and cracked. The iron of the augite appears to be completely used up in forming the biotite, for though a few grains of magnetite occur, these are due to the subsequent hydration of the mica accompanied by the formation of a chloritic mineral. A little hornblende is present, apparently secondary, after augite.

(2) An augite-syenite from Svenöre well shows the conversion of augite into dark mica. This rock is closely allied to the well-known Lauvigite. The felspars are orthoclase, apparently of two varieties, with a little plagioclase. They exhibit microperthitic intergrowth, and this in many places at their margins passes into micropegmatite. The augite is of two types: (i) Pale brown, slightly pleochroic, showing, in the central portions of the crystals, good cleavage marked by the deposition of iron oxide in the cracks, which occasionally assumes the form of negative crystals. Incipient diallagic cleavage may be observed, traversing the earlier prismatic one. This augite is much corroded by the felspars, its margin being in some places curiously broken up and intergrown with the

[1] Q.J.G.S., vol. liii, p. 405.

[2] I am indebted to Professor Bonney for the opportunity of studying these slices, which belong to his collection.

surrounding felspar in a manner approaching micropegmatite. (ii) A pale-green augite, irregularly cracked, probably sahlite. It occurs in rounded fragments, which in places have been broken up and separated. Biotite is chiefly developed round the first-named augite, and it occurs only when that mineral is in contact with the felspar, and has been manifestly corroded by it. With ordinary light it is often impossible to say where the passage of augite into mica commences, for its first manifestation is a very faint brown tinting. With crossed nicols the first indication of its development is a marked increase of intensity in the polarization tints, along a narrow zone at the junction; this presently shows the characteristic mica cleavage, and varies in colour from a very light brown to a dark bright brown. Beyond the latter magnetite is developed. On the other side of the mass of magnetite the augite shows irregular cracks in which the magnetite is deposited, and beyond this the regular cleavage sets by marked iron oxide, as mentioned above. It should be understood that though this *order of sequence* is apparently constant, yet any stage owing to the irregularities of the decomposition may be locally very poorly shown or even absent. In some cases the augite is completely decomposed, and there remains only a core of magnetite with a corona of mica, darker in colour near it and lighter in contact with the felspar. The pale-green augite does not so readily develop mica as the other variety, though its smaller fragments show in places an abundant marginal growth.

Much serpentinization occurs along its cracks, accompanied by the formation of a little mica. Both these facts confirm the idea that this is a non-aluminous augite. It is, however, rich in iron oxide, which is largely excreted in the formation of mica and the serpentinization. Apatite is an abundant constituent of the rock, the larger crystals acting as the nuclei round which the augite consolidated.

(3) A similar formation of dark mica from augite may be observed in Lauvigite, which closely resembles the Svenöre syenite described above. The rock is too well known to require detailed description, but in the present connection the following points may be noted. The augite is of two types: (i) pale-brown, slightly pleochroic, with incipient diallagic cleavage; (ii) pale-green sahlite, irregularly cracked, some serpentine and a little biotite forming along the cracks. This is earlier than the first-named augite and in many places is enclosed by it. The felspathic mixture (anorthite, microperthite) has much corroded the augite, with which at its margins it is in places intimately intergrown. Round the augite mica is developed, the one passing almost insensibly into the other as already described, and the same darkening of the mica and final formation of magnetite occurs as the distance from the felspar increases. The felspathic magma has in places invaded the augite, producing in its centre patches of dark mica which appear at first sight to be isolated inclusions. Here also the mica is only formed with difficulty in the sahlite.

(4) A gabbro from Humlebäk affords an interesting example of the corrosion of a felspar by augitic magma, resulting in the formation of brown mica. In this case the felspar is labradorite, occurring in idiomorphic crystals, round which the augite, a colourless variety, extends in ophitic fashion. The felspars are much corroded and in part melted down, thus enclosing small portions of the augite. Round the edges of the felspar, mica is developed, appearing at the outset as a faint brown tinting of the augite. At first the cleavage of this mineral is alone apparent as a rule, though occasionally traces of the mica cleavage may be discovered parallel to one of the cleavage planes of the augite. There are indications that at this earliest stage a mixture of augite and mica is present, or rather, a *solution* of mica in the augite is suggested. In one instance where a felspar lath is surrounded by biotite, obviously derived from augite, it has lost almost half its bulk by corrosion, and the remainder appears to be permeated by augitic material, converting it into a colourless mica whose cleavage planes are continuous with those of the biotite on each side. The mica when traced inwards from the margin of the augite loses its scaly appearance, due to the cleavage of that mineral, becomes more compact, and develops its own cleavage. At first it is a straw colour, then it becomes a dark bright brown, and finally magnetite is formed; and in the larger augite grains this is followed by an irregularly cracked zone which passes into a central portion showing fine cleavage striation. With this, as a rule, the outer portion is in optical continuity. When the augite is more remote from and unaltered by the felspar, it is twinned sometimes more than once parallel to the orthopinacoid; this, combined with basal cleavage striation, giving the well-known herring-bone structure. In the smaller augite grains the conversion into mica and magnetite is sometimes complete, a corona of light mica surrounding the bright brown mica, and in most cases a core of magnetite occupying the centre of the grain. The following explanation may be offered of the transition shown in this rock and the syenites:—where the felspar is in contact with the augite a mica is formed, poor in iron and rich in alumina, probably phlogopite, while, as the distance from the felspar increases, ferric oxide takes the place of alumina, resulting in lepidomelane, biotite being formed as an intermediate stage, and finally, beyond the limit to which the felspathic magma permeated, magnetite is excreted.

Thus the normal order of change seems to be as follows (commencing from the side of the felspar): (1) fusion of felspar and augite with faint brown tinting of the augite, due to incipient development of mica; (2) pale-brown mica (phlogopite); (3) biotite; (4) dark red-brown mica (lepidomelane); (5) intimate mixture of dark mica and magnetite; (6) mass of magnetite; (7) augite with irregular cracks in which magnetite is excreted, which is followed by augite with fine cleavage striation.

VII.—The Rate of Erosion of some River Valleys.

By C. C. Brittlebank, Esq.

(Read before the Geological Section of the Australasian Association for the Advancement of Science, Melbourne Meeting, January, 1900.)

THE district in which these observations have been made is a very suitable one for such experiments, and is situated from 2 to 12 miles from Bacchus Marsh and from 32 to 54 miles west of Melbourne.

The chief streams which pass through the above area are the Werribee and Lerderderg Rivers with their tributary creeks. The country is somewhat rough, being intersected by numerous deep gorges and wide flat-bottomed valleys.

Early in 1892, when working on the glacial deposits of Bacchus Marsh, I was greatly astonished at the immense amount of work done by those puny streams, which have in places cut fairly narrow gorges and valleys through solid rock, to a depth in one place of at least over 1,000 feet.

It occurred to me that, if by any means I was able to ascertain the amount of rock worn off the river bed within a given time, I should be able to arrive at an approximate estimate of the time the rivers have been cutting their channels. Even without detailed observation we should expect that a vast period had elapsed since the streams first ran on the surface of the basaltic tableland. I was, however, hardly prepared for the enormous time which my observations show, more especially as the erosion is subsequent to the flow of newer basalt.

After thinking the matter over, and striving to devise some method other than the level, I hit on a somewhat rough and ready plan, and it is from these measurements, taken over a period of five years, that my provisional estimate has been obtained. My method is as follows:—A number of holes are drilled in lines across the river bottom—if in soft rock, one inch in diameter by three inches deep, and one inch by two inches in hard dense rocks. Into these holes are placed a number of wires which have been carefully measured, cut, and fastened by solder into small bundles containing from 20 to 100 according to the hardness of the rock. The wires being placed in the holes with the longest wire exactly flush with the rock surface, cement is poured in and allowed to harden. As various kinds of wire have been used in the softer rocks, a strip of slate pencil of equal length to the longest wire is placed in each hole; this acts as a check on the wire in case of corrosive action.

Now as the surface of the river bed is worn away the end of a fresh wire is exposed for every hundredth part of an inch removed from the harder rocks, and one for every fifth or twentieth of an inch in the softer rocks.

There is reason to suspect from geological evidence that the gorge of the Lerderderg River above the alluvial flats is of much greater age than that of the Werribee. Prior to the flow of newer basalt the Lerderderg had cut a fairly deep channel, as had also the

ancient Werribee, but the latter was blotted out of existence by the flows of basalt. The Lerderderg, being guarded by high Silurian ranges on the south over which the lava did not rise, continued in the same channel as it now occupies. I will therefore confine my remarks to the Werribee and tributary creeks.

The formations through which the Werribee has cut are: Lower Silurian (Ordovician), granite, Glacial Series, fresh-water 'Miocene' gravels, and basalts, both older and newer. The newer basalt has at one time formed an extensive plateau from Mt. Blackwood, the Lerderderg Ranges, and Ballan on the W. and N.W. to the Brisbane Range and the plains on the S. and S.E. The surface slope is to the S.E., and is broken here and there by ridges and hills of the various older formations which stand at a higher level. In making my observations I have used the present surface of the basaltic plateau as a bench mark. Careful measurements have been taken from the surface to the river bed at all places where erosive action is being checked.

The different rocks through which the rivers have cut their valleys greatly influence the amount and direction of erosion and denudation. I find that the resistance offered by the various geological formations to the erosive power of river action is in the following order: Basalt, Silurian Granite, Glacial Series, Miocene ferruginous gravels. Jointing, dip, strike, dykes, and bands of hard rock have considerable influence in aiding or retarding the river action. Fallen rock masses, especially huge blocks, check erosion to a considerable extent. A band of hard rock crossing the river valley acts in two ways, first by contracting the channel and second by checking vertical erosion below its own level on the up side. Numbers of these bands cross the stream, and many of my observations have been taken from them. Probably the best position for observing the wearing of any river channel is at the outer angle of a sharp bend. At such places the bed is almost always free from boulders, gravel and sand. Moreover, by the constant undermining action of the river an almost vertical cliff is formed on the outer bend. The greatest advantage, however, lies in the fact that the upper part of the river rarely moves from side to side, but cuts a fairly straight course through the country.

I had expected that the erosion of the river valleys would be carried on at a comparatively rapid rate, but after many observations along their courses I find the amount removed in a period of five years is very small, so small in fact that had the amount not been checked at numerous points I should hesitate to place on record the results, but having undertaken the observations with this object in view I give the average obtained at many separate stations on the Werribee and tributary creeks.

Basalt	...	...	0·02	inches in	5	years =	1 inch in	250 years.
Silurian	...	...	0·03	,,	,,	=	,,	$166\frac{2}{3}$,,
Granite	...	...	0·04	,,	,,	=	,,	125 ,,
Glacial	...	...	0·05	,,	,,	=	,,	100 ,,

Having ascertained the amount of erosion over a given period, it

is necessary to calculate the time taken to cut the cliff sections. To be as brief as possible I have selected three sections on the Werribee between Bacchus Marsh and Ballan.

	Thickness.	Time required for cutting.
(1) Glacial	195 feet	234,000 years.
Silurian	415 ,, ...	830,000 ,,
Total	610 ,, ...	1,064,000 ,,
(2) Basalt	235 ,, ...	705,000 ,,
Glacial	60 ,, ...	72,000 ,,
Granite	176 ,, ...	264,000 ,,
Total	471 ,, ...	1,041,000 ,,
(3) Basalt	240 ,, ...	720,000 ,,
Glacial	98 ,, ...	117,600 ,,
Silurian	122 ,, ...	244,000 ,,
Total	460 ,, ...	1,081,600 ,,

In compiling these notes I have assumed that the rainfall has not been greater in past ages, say since the flow of newer basalt, than it is on the average at the present time.

VIII.—On the Naparima Rocks, Trinidad.

By R. J. Lechmere Guppy, Esq.

I HAVE received a copy of the paper by Messrs. Harrison and Jukes-Browne on the Oceanic Deposits of Trinidad, and wish to place on record a few remarks on it.

In the first place I must compliment these gentlemen upon the manner, at the same time courteous and impartial, in which they have dealt with my work.

Our authors state that my writings leave both the nomenclature and the succession of the Trinidad Tertiaries in a very uncertain state. I am afraid that there is much of truth in this statement; and I should feel satisfaction could I clear up the uncertainty either by producing evidence of a nature distinctly confirming or distinctly refuting Professor Harrison's opinion that the Nariva Series is older than the other Naparima beds, and that the Sanfernando beds are closely connected with and are probably an upward continuation of the Nariva Series. I have not been able to satisfy myself with positive certainty either one way or the other. Our authors admit themselves that no sections were seen showing the junction of the two formations, but they consider that there is abundant evidence that the two series occupy the relative positions assigned to them by the geological surveyors. I am not so wedded to my own opinion that I would not welcome theirs if I could be satisfied about this evidence. But so far as I know, no evidence of a conclusive nature is forthcoming, as in no place is the junction of the two series seen. A similar doubt formerly prevailed respecting the junction of radiolarian and foraminiferal beds; but this has been dispelled,

and we are now aware that these two series pass gradually and conformably one into the other. A similar result may hereafter happen in regard to the Naparima marls and the Nariva Series. In the meantime my opinion is based mainly upon conjecture, though one point weighs a good deal with me, that is, the strong resemblance of the Nariva beds to the strata now being deposited in the gulf derived from the degradation of the Naparima beds; and if this inference is correct the Nariva Series must be later in date than the foraminiferal marls. The resemblance I refer to is one not only of mineral composition and mechanical aggregation, but of organic contents, inasmuch as some of the deposits now being laid down and (notably those off the mouth of the Sipero river) contain foraminifera of the same character and in similar condition and of similar frequency of occurrence as the Nariva beds. To take an example, *Globigerina* is a very abundant organism, both in the mud deposits off Sanfernando and in the Nariva beds, but in both these deposits it is relatively much less abundant than in the foraminiferal marls; and the relative infrequency of occurrence is due to the destruction of the fossils in the course of the denudation and redeposition of the marls. No such foraminifera now exist or can exist in a living state in the gulf, though in my very first dredgings off Sanfernando I recorded *Globigerina* at every haul in shallow water near the shore. That was before I had recognized *Globigerina* in the rocks of Naparima, and, as I have already stated, the foraminifera so dredged by me were fossils derived from the Naparima marls. Also, I consider that the abundance of gypsum in the Nariva Series is due to the breaking down and redeposition of the foraminiferal marls, in course of which the carbonate of lime existing in the latter was partly changed into sulphate.

Respecting the nature and origin of the Argiline of Naparima Hill, I somewhat timidly expressed my opinion in former papers. As I find that Messrs. Harrison and Jukes-Browne are substantially of the same opinion as myself on the subject, I may take the opportunity of restating it. The nature and origin of the Argiline are similar to those of the Naparima foraminiferal and radiolarian marls, and it contained similar Radiolaria and Foraminifera. But the Argiline has undergone a change consequent upon an alteration in the form of its silica; a change analogous to that which has taken place in part of the so-called 'cement' of the White Hills of Bendigo, Australia, described by me in the Proceedings of the Geologists' Association of London, 1864, p. 409, and which consists in an induration by probably a partial solution and redeposition of the siliceous constituents. The whole mass of Naparima Hill is thus affected; but a similar change has partially and locally affected other portions of the Naparima rocks.

To my description of the Argiline of Naparima Hill published in the Geological Society's Journal, November, 1892, p. 526, should be added the remarks contained in my paper in the Trinidad Field Naturalists' Journal, 1893, p. 7, as follows: "Beds of different texture occur in the Argiline, some being more sandy in composition.

In these I have found very evident organic remains, though I cannot yet say exactly what they are. In another stratum of the same rock, I found two or three identifiable Foraminifera, namely, *Pullenia* and *Sphæroidina*, both deep-water forms." J. W. Gregory found indeterminable fragments of Radiolaria in this rock, and I can confirm this observation, such remains being abundant.

It is singular that no attempt was ever made to ascertain whether water could be obtained from beneath the Naparima Rocks. Previous to my arrival in the island (1859), the Government offered a reward of £2,000 for the discovery of water by means of an artesian well in Naparima. One would have thought that that would have been sufficient encouragement for such an attempt. A close examination of the physical features and geology of the country might afford to an observant eye and a sanguine mind further encouragement for a prosecution of the search for subterranean water. In my paper on the water-bearing capacities of Trinidad Rocks (published in the Trinidad Agricultural Record, 1891), also in my paper in the Journal of the Geological Society already quoted, I gave a description of the marls of Naparima, showing that these rocks do not yield springs, nor do they contain water except in union with the rock. It is true the rock (marl) is capable of union with any quantity of water, but it will not give up this water except by the process of evaporation. I had not mentioned the fact, however, that in one or two places in Naparima there are at the bottom of ravines or gullies springs of water which, though too small to give rise to any stream, being rapidly absorbed by the soil or dissipated by evaporation, serve to a very limited extent for drinking and washing purposes. Their existence is usually obvious to the wayfarer, for they assail his senses by the view of linen spread on bush and grass, the smell of foul water, and the noise of banging and beating of clothes characteristic of the Creole way of washing. Now it has occurred to me that these springs arise from the rock vertically underlying the marls, and that they only occur where the depth of the marl above the underlying rock is not great. This underlying or hypogene rock I suppose to be an extension of the hypogene or granitoid rocks of South America.

I am satisfied now that the Naparima deposits are not a continuous series of formations of several thousands of feet in thickness, but that the rocks as shown in section are several repetitions of the same beds or series of beds. As these beds are now almost vertical, it is evident that the movements which have brought about the alteration in position have been very extensive, and the intermediate and connecting portions of the strata have been removed by denudation.

In my paper on the Gulf of Paria, printed in the Proceedings of the Victoria Institute of Trinidad, 1894, p. 106, I touched cursorily on the remarkable depression between Trinidad and Venezuela passing through the Bocas. I reproduce here what I there wrote :—

"The Bocas are narrow channels connecting the Gulf of Paria with the Caribean Sea. These channels have had their origin

as subærial valleys, now submerged. (See papers in Proceedings Scientific Association, 1877, p. 103, and Agricultural Record, 1891, p. 79.) The first Boca (Boca de Monos) is barely half a mile wide, the second (Boca Huevos) a little wider. The third (Boca Navios, so called, I suppose, because ships do not use it), about the same. The Grand Boca is about six miles wide. These widths may be taken to be the clear widths in the narrowest parts. The rapid currents through these channels have kept them scoured out, and the depth reaches 120 fathoms. No mud or sand of any kind is deposited in these Bocas. The bottom is one of rocky inequalities whose existence is evidenced in the violent eddies and ripples of the so-called 'remu,' a phenomenon which occurs when the water outside the Bocas is at its lowest and consequently the water surface gradient from the middle parts of the Gulf the greatest. Outside the Gulf the Caribean Sea varies in depth from 20 to 60 fathoms except in the line of the great downthrow passing along the axis of the Grand Boca. Here the depth attains 120 fathoms, and is probably not less than 90 in any part. This line of depression seems to be a terrestrial feature of some magnitude. Its extension north-eastward from the Boca Grande, between the islands of Grenada and Tobago, is indicated by deep water marking the boundary between the volcanic region of the Antilles and the non-volcanic region to the south and east thereof."

It is strange now to myself that in writing my paper on the Microzoic Deposits of Trinidad I should have given so little weight to the bearing the existence of this depression must have on any theory of the movements of the earth's crust in this region. I am unable now to go further into this subject, but I cannot forbear pointing out that this great depression of a portion of the earth's surface, which evidence clearly shows to have been formerly a continuous land surface, had most probably an intimate connection with, or rather was part of, those movements, which among other events broke up and elevated the Naparima Rocks and tilted them on edge.

IX.—Two New Species of Ostracoda of Tithonian Age from Nesselsdorf, Austria.

By Frederick Chapman, A.L.S., F.R.M.S.

THE following descriptions of Ostracoda from the Tithonian of Austria relate to specimens kindly forwarded to me by Dr. M. Remeš. They were obtained, together with numerous other fossils, including Foraminifera, from the Red Limestone of Nesselsdorf.

The Ostracoda seem to be very rare in these beds, for the two specimens now described were the only forms obtained by Dr. Remeš, whilst other microzoa were fairly numerous.

Bythocypris, G. S. Brady [1880].

Bythocypris (?) *Jurassica*, sp. nov. (Figs. 1*a–c*.)

Carapace somewhat compressed; from the side subreniform, the greatest height a little in front of the middle, anterior extremity broad and rounded, posterior rounded but narrower. Edge view,

anteriorly rather sharp, posteriorly slightly swollen. End view, dorsal edge acute, ventral well-rounded. Surface of shell finely punctate; this latter feature renders the generic determination as *Bythocypris* a little doubtful. Length, ·56 mm.; height, ·26 mm.; thickness of carapace, 18 mm.

From the Red Limestone of Nesselsdorf, Austria (Tithonian).

This species approaches *B. reniformis*, Brady,[1] in general form, but in the side view of the latter, the posterior extremity is more broadly rounded.

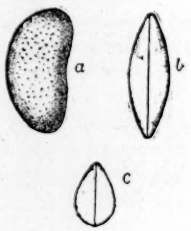

FIG. 1.—*Bythocypris Jurassica*, sp. nov. × 30.

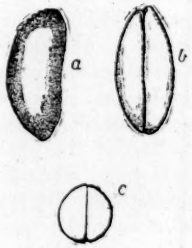

FIG. 2.—*Bairdia Nusseldorfensis*, sp. nov. × 30.

BAIRDIA, McCoy [1844].

Bairdia Nesselsdorfensis, sp. nov. (Figs. 2*a–c*.)

Lateral view of carapace subtriangular, dorsal margin boldly arched, ventral nearly straight, but slightly incurved near the lowest third. The postero-dorsal margin incurved, postero-ventral angle rounded. The antero-dorsal margin with numerous small and pointed tubercles. Edge view elliptical, with rounded ends; edges of right valve embraced by the left. End view subcircular.

Length, ·6 mm.; height, ·25 mm.; thickness of carapace, ·26 mm.

From the Red Limestone of Nesselsdorf, Austria (Tithonian).

REVIEWS.

I.—ON A COLLECTION OF STONE IMPLEMENTS IN THE MAYER MUSEUM, MADE BY MR. H. W. SETON-KARR IN THE MINES OF THE ANCIENT EGYPTIANS, DISCOVERED BY HIM ON THE PLATEAUX OF THE NILE VALLEY. By HENRY O. FORBES, LL.D., Director of Museums to the Corporation of Liverpool. Reprinted from Bulletin Liverpool Museum, II, Nos. 3 and 4 (20th January, 1900). With Illustrations.

WE have here the results of Mr. H. W. Seton-Karr's examination and survey of the district where he collected stone implements in two of his Egyptian journeys (1896 and 1897), together with his account of the conditions under which they occur on the surface of a part of the Eastern Egyptian Desert, traversed by the Wady el Sheikh, about 50 miles long, from S.E. to N.W., and entering the

[1] Rep. Chall., 1880, Zool., pt. iii, p. 46, pl. v, figs. 1*a–l*.

right bank of the Nile opposite El Fent, which is on the Cairo-Assiout railroad, half-way between the stations of Feshn and Maghagha. Rising up from the Wady el Sheikh are the escarpments of three successive plateaux (the lowest about 400 feet high, the highest about 700 feet). They consist of Cretaceous (latest) limestone below and Eocene (Nummulitic) limestone above, all bearing flint nodules.

The worked flints occur in either isolated or continuous heaps of débris thrown out from the many quarries or mines, either on the edges or the surface of the plateaux, mostly on the right side of the Wady. Flint-workings had been cursorily noticed in this region by Greg and Johnson. Mr. Seton-Karr, however, designedly visited them, and made a careful survey. The mines or pits are about two feet in diameter, and not deep, nor showing lateral galleries. They are more or less choked with blown sand. The excavated material has been piled up around the mouth of the pit and the implement-maker's workshop. Similar pits were examined by Mr. H. Seton-Karr in 1896 in the Wady Sojoor, about ten miles to the south. A serviceable map and six excellent photographic views of the plateaux and their special features (pp. 81, 101–104) enable the reader to master the topographical details.

Dr. H. O. Forbes gives careful descriptions of a selection of 47 from the 2,000 specimens (pp. 78–80 and 97–105), together with good clear figures, after photographs (pp. 82–96). The heaps of refuse at the different sinkings for the most part contained different kinds of implements. The author's conclusions as to the relative age and origin of the mines and specimens are careful, liberal, and sound.

Judging from the plates and the descriptive notes, we can enumerate the several kinds of flint-work treated of. The author's grouping is preserved:—

a. Thin-edged discs; in many cases neatly dressed on the surface and perforated in the middle, the central opening being widened until a narrow delicate ring has been worked out, for bangles, etc. (Pages 78–80.)

b. Axes, chisels, hoes, etc.; of triangular shape (6 in. to 9 in. long), broad at one end and tapering at the other (butt end). Broad end sometimes subacute or somewhat narrowed by rounding; thus figs. 14 and 16 are variants; the former has the broad end subacute, the latter is narrower throughout. (Pages 80 and 97.)

c. Leaf-shaped; figs. 18 and 19 more symmetrically chipped; almost equally convex on the two faces; more rounded at one end than at the other. (Page 97.)

d. Knife-like; figs. 20 to 35 (pages 97, 98). Many carefully dressed flakes (about 6 in. to 9 in. long) good for cutting, flaying, scraping, etc., with sharp edges, and having one edge more convex than the other, but in some cases almost symmetrical and even quite equal (fig. 24). Some, neat in shape, are like the Danish knives and daggers; others have a sharp-edged portion irregular in shape (figs. 30–33), and the other part reduced by chipping to a narrow

handle or tang. Fig. 34 is a roughly chipped three-sided piece of flint, "partly blocked out" for a knife possibly. Fig. 35 is a flat, curved, sharp-edged blade, probably broken in the making.

e. Agricultural implements, etc. Fig. 36 is a nearly symmetrical truncheon or beater, of a thick spatula-shape, with a knob at the narrow end; it is very common. Fig. 37 has a coarse, thick blade, triangular in section and sharpened along one edge, and the butt end is deeply chipped for a tang. This large chopper-like implement ($8\frac{1}{2}$ in. by $2\frac{1}{4}$ in.) is of common occurrence, and must have been an efficient tool in the hands of the old labourers. Fig. 38 (from Wady Sojoor), p. 99, another large anomalous tool ($8\frac{3}{16}$ in. by $7\frac{9}{16}$ in.) flat and quadrangular or diamond-shaped, with the angles distinct, one of them very prominent, is carefully chipped along its edges.

f. Figs. 39 and 40 are two small subglobose hammer-stones (3 in. by $2\frac{1}{2}$ in.), bearing marks of wear.

g. Scrapers (p. 99). Fig. 45, large, comma-shaped; broad and rounded at one end, tapering and curved at the other, where one edge has been hollowed as a concave and hooked scraper. Fig. 46 (from the Plateau of Thebes) is a rough and irregular flake, broad at one end, narrow at the other; dressed along the edges, one of which bears a small semicircular hollow. Fig. 47 is a roughly dressed, somewhat semicircular flake, with a definite concave hollow at the middle of the edge, suitable for scraping and shaping round staves and sticks.

h. Cores, and the narrow flakes struck off from them, are common; one long hoof-shaped core is shown by fig. 42.

i. Nondescripts. Fig. 41 is a long, narrow, and very coarsely dressed, three-sided flake (17 in. by $3\frac{1}{2}$ in.), sharp at the ends. Fig. 43 is a rough flake, possibly an early state of some such an implement as that of figs. 26 or 27.

Dr. Forbes now takes into consideration "What is the age of these implements from Wady el Sheikh and Wady Sojoor, and how long probably were the mines worked?" "No find of implements so extensive as the one which is the subject of this paper has ever been made in Egypt; nor had any previously been found in relation to the mines which supplied the material, or to the workshops in which they were fabricated." Therefore archæologists may expect much from the careful study of this undisturbed locality.

Introducing these very ancient Egyptian relics to the people of to-day, who may be looking at them in the Liverpool or other Museums, the author explains first of all, briefly, that implements of stone have been in use down to the present from very early, even geological, times; more especially (1) as rough and merely chipped and flaked pieces of siliceous rock (flint, quartzite, and other varieties), so abundant in certain old gravel beds that they characterize a long-past period of time called the Palæolithic Age. (2) Instead of stones merely chipped into useful shapes, in many places gravels and loams deposited in much later times contain well-dressed and polished implements of stone; and these, being characteristic of newer periods, are termed 'Neolithic.' (3) As stone tools,

in process of making, pass through rough-chipped to more finished, smoother, and polished shapes, it happens that sometimes all sorts occur together; and, indeed, prejudice and fashion, as well as convenience, kept old forms in use until, as at the present day, the more finished and best adapted stone implements only are used, after having been made from such natural material as is most fit and ready to hand.

The relative age or chronology of old worked stones can be decided only when the natural deposit, or artificial heap of débris, in which they are found can be definitely referred to some unit in a geological or historical standard. The shape by itself is a guide of limited value, except for neoliths; the colour and the patination are other guides that cannot be taken alone. The varieties of patination and tint, due to exposure on the desert, are carefully dealt with at pages 106, 107, 110, and 111, and are not found serviceable in fixing the age of this crowd of Egyptian specimens.

Forms similar to many of them have been found (as the author insists) in the ruins of Kahum (explored by Professor Petrie), which was built in the Twelfth Dynasty, at least 2660 B.C. (pages 108–110); and, just as neoliths are found there with palæolithic forms, so in the Wady el Sheikh and Wady Sojoor the fine workmanship of bangle-rings (pl. i) and very neat dagger-knives (figs. 24, 26, and 28) is associated with the many rude and very rude examples among the other figures. The latter may be more or less exactly matched with specimens of neolithic and early historic periods from localities at home and abroad. The few that approximate to the so-called 'spear-head' and 'leaf-shape' forms (figs. 11, 13, 14, 16, 18, and 19) found in real Palæolithic gravels are not proofs that Palæolithic Man worked these stone-pits; they are variants in the old Egyptian workshops, and may be matched with neolithic and historic finds in museums and archæological books.

It may be noticed that the Egyptian paintings of the flint-knife manufacture, in the tombs of Beni Hasan (reproduced at pages 108, 109), present outlines comparable with some of Dr. Forbes's figures, and are said to be of the same age as the Kahum ruins.

Other occurrences of stone tools, flakes, and flint nodules, have been noted by Petrie, Quibell, and Seton-Karr, on the Egyptian plateaux bordering the Nile. They lie in groups scattered around working places; and the author doubts if the great pluvial denudation since the time of the European Palæolithic age would not have carried away the loose débris, whilst cutting the Wadys down from the plateaux into the great Nile Valley.

Dr. Forbes has done good service in giving us this example of the value of the indestructible direct evidence of the past, better than the best papyrus and parchment of versatile history. He shows that these veritable evidences of Early Man in Egypt, though not much less than 5,000 years old, are not, like those from the old gravel found by the late Pitt-Rivers, of real Palæolithic age.

T. R. J.

II.—A Monograph of Christmas Island (Indian Ocean): Physical Features and Geology. By C. W. Andrews. With descriptions of the Fauna and Flora by numerous contributors. 8vo; pp. xiii, 337, 22 plates, 1 map, text illustrated. (London: printed by order of the Trustees of the British Museum, 1900.)

THE present work is the first monograph issued by the Trustees of the Natural History Branch of the British Museum dealing with the fauna and flora, the geology and palæontology, of a single geographical unit of the globe, and owes its inception to the advocacy of the Assistant-Secretary, Mr. Charles E. Fagan, F.R.G.S., who has, we learn, greatly interested himself in its publication.

The little island that forms the subject of this monograph lies to the south of Java, 190 miles from its shores, and must not be confused with its namesake in the Pacific Ocean.

This almost undisturbed little spot of land, 12 miles by 9, is now being opened up for commercial purposes, and it seemed desirable that before its primitive fauna and flora were ousted by man, a careful record of them should be made, whilst at the same time it appeared likely that its geological investigation would throw light on the origin of coral islands, of which it was manifestly one. Accordingly, Sir John Murray having agreed to provide the requisite funds, the Trustees of the British Museum granted the necessary leave of absence to Dr. C. W. Andrews, whose selection for the purpose of carrying out the investigation is seen by the present volume to have been most amply justified.[1]

With the zoological and botanical results of the expedition, interesting and important though they be, we have nothing to do in these pages. The facts ascertained concerning the geological structure of the island show that it presents some important peculiarities, differentiating it from other oceanic islands, and difficult to explain. It is, in fact, the flat summit of a submarine mountain, whose steep slopes sink rapidly to a depth of over 14,000 feet below the sea. The summit of this mountain peak is formed of a succession of tertiary limestones ranging in age from the Eocene (or Oligocene) up to recent reef-deposits, with intercalations in the older beds of volcanic rocks.

The tertiary beds, especially the Miocene orbitoidal limestones, end abruptly on the coast in vertical cliffs, sometimes 250 feet high: they must therefore at one time have covered a far wider area, and have been reduced by peripheral faulting.

The principal volcanic rocks are the basalts and basic tuffs at the base of the Miocene limestone, separating it from the Eocene (or Oligocene) beds below, and the basalts and trachytes underlying the latter. These older eruptive rocks form the basis of the island, which basis Dr. Andrews considers "is almost certainly a volcanic

[1] We published some Notes of an expedition to Christmas Island by C.W. Andrews (reprinted from the author's paper read before the Royal Geographical Society, November 28, 1898) in the Geological Magazine, Dec. IV, Vol. VI (1899), pp. 19–27.

peak." We venture to think, however, that this assertion, qualified though it be, is still rather stronger than the evidence.

Owing to the dolomitization and phosphatization of the limestones the palæontological collections were not rich. The few Molluscan remains obtained are described by Mr. R. B. Newton. The corals, which were more abundant, but still not in so satisfactory a condition as could be desired, were carefully worked out by Dr. Gregory, and include representatives of nineteen determinable species, of which eight are new. Their general character is typically Indo-Pacific.

The Foraminifera, of which the limestones, especially the Miocene (orbitoidal), are largely composed, had mainly to be studied from sections, and are reported on by those past masters of the subject, Professor T. Rupert Jones and Mr. F. Chapman, who have made their work as comprehensive as possible in the time, and hope at some future date to furnish further details. Unfortunately, beyond a "list of species of Orbitoides" there is no summary of the results set forth in the thirty-nine pages to which their report extends.

A "note on the composition of some dolomitic and other limestones" from the island, by Mr. E. W. Skeats, completes the geological matter in the monograph.

As regards the get-up of the work, we are glad to note that the print is better than in many Government publications with which we are acquainted, whilst the plates, although somewhat closely cut, are of the quality which we have become accustomed to expect in the publications of the British Museum. Concerning the views reproduced in the text, however, we prefer to be silent: our remarks might be considered libellous. B. B. W.

III. — Report on the Great Earthquake of June 12th, 1897. By R. D. Oldham, A.R.S.M., F.G.S., Superintendent, Geological Survey of India. Mem. Geol. Survey of India, vol. xxix. (Calcutta, 1899.)

PHYSICAL geologists will with one accord be grateful to Mr. Oldham for his admirable report on the Indian earthquake of 1897. Chief among modern shocks, if not among all recorded shocks, the wonderful phenomena which it presented, and the wide area over which they were observed, combined to render the earthquake in every way remarkable and deserving of the most careful study. Fortunately, it was possible to give to it the attention which its exceptional character demanded. Four officers of the Indian Geological Survey were despatched to different parts of the area chiefly affected, and, about six months later, Mr. Oldham made as thorough an examination of the epicentral tract as his limited time and the impracticable nature of the country would allow. The results of all this labour are as important as they are novel and interesting; and those who have been engaged in similar work will be the first to recognize that we are here presented with a record report as well as a record earthquake.

The study of such an earthquake must have been an almost unalloyed pleasure to its investigator. There was no need to spend

three or four months in flooding the disturbed area with circulars, though work of this kind had of course to be done. The materials to be collected were not the fleeting impressions of a transitory phenomenon; they were for the most part permanent effects that could be examined without haste, suffering little from the lapse of time and nothing at all from defects of the human mind. They had to be observed, disentangled, and classified,—no light work, rather one requiring, and, what is more, obtaining, the best energies of a capable field-geologist.

It would not be easy within moderate limits to refer to all the points of interest that are to be found in this report. Though filling a complete volume of the Memoirs, and extending to more than 400 pages, it should be read from cover to cover, not by seismologists alone, but by every geologist who wishes to study the mechanics of mountain-building or to realize the scale on which the operations of nature are sometimes carried out. In doing this, he will no doubt be struck by some passages more than by others. Among them he will probably include the descriptions of the fissures that were formed in alluvial ground far away from river-banks, etc. (pp. 88–94), of sand-vents and the forcing up of river-beds and the bottoms of wells (pp. 99–107), and of the numerous landslips (pp. 111–123); the chapter on the earthquake-sound and on Barisâl guns (pp. 191–207); the investigation of the velocity of the earth-wave within the disturbed area (pp. 53–77), and the tracking of the unfelt vibrations through the body of the earth and of the surface-undulations almost completely round the globe (pp. 227–256). To the physicist the last-named chapter will prove the most interesting; but the geologist will probably regard with the highest favour that which deals with the permanent changes in the epicentral tract. Here we have described the Chedrang fault-scarp (pp. 138–147), which crosses many times the river of that name, forming a series of waterfalls and lakelets along its course; the Bordwar fracture (pp. 148–151); numerous pools, due to a reversal of drainage, but without any visible connection with faulting (pp. 152–157); changes of level evidenced by the visibility of rivers and roads formerly hidden by intervening hills (pp. 157–163); and, in an appendix which properly belongs to this chapter, an account of the re-survey of certain trigonometrical stations within the epicentral area (pp. 361–371), the chief result of which is to show the urgent need of its repetition on a much larger scale.

Exceptional as the Indian earthquake was, one cannot read without astonishment of the vast district over which these permanent changes took place. Mr. Oldham estimates that it was about 200 miles in length, not less than 50 miles in breadth, and more than 6,000 square miles in area. The fault-scarps and fractures discovered within it are merely evidences of displacements continued up to the surface. They manifest the extreme complexity of the earthquake's origin, which Mr. Oldham traces to a slide along a huge, but hidden, thrust-plane, inevitably accompanied by nearly simultaneous and more or less visible movements along the minor faults connected with it.

The volume is illustrated by 44 plates and 3 maps, in addition to a large number of woodcuts. There are pictures of damaged and utterly ruined houses, monuments overthrown and twisted on their bases, railway lines crumpled as if they were made of wire, and fissures, sand-vents, and fault-scarps, as well as the diagrams of distant magnetographs and horizontal pendulums. Many of these are worthy of a wider circulation, and will doubtless live again in books made better by their presence. C. Davison.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—May 23, 1900.—J. J. H. Teall, Esq., M.A., F.R.S., President, in the Chair. The following communications were read :—

1. "The Igneous Rocks of the Coast of County Waterford." By F. R. Cowper Reed, Esq., M.A., F.G.S.

The first part of this paper is devoted to a discussion of the field-evidence, as shown by the coast-sections from Newtown Head to Stradbally. The igneous rocks there exposed are divided into the following six categories :—(*a*) The felsitic rocks; (*b*) necks of non-volcanic materials; (*c*) the basic sills and vents; (*d*) intrusions of dolerite; (*e*) intrusions of trachyte, andesite, etc.; (*f*) intrusions of other types. In regard to the age of the rocks, there appear to have been two main periods of volcanic activity: the first, in Ordovician times, was marked solely by outpourings of a felsitic nature; the second, post-Ordovician but pre-Upper Old Red Sandstone, was characterized by a succession of several distinct types of igneous rocks. The lavas and tuffs, interbedded with fossiliferous rocks, have been already described. These are overlain by other felsites and ashes, developed near Great Newtown Head, which show the same dip and strike and partake in the same movements. Next occurred an outburst of green and pink felsites, tuffs, and coarse agglomerates, developed from Great Newtown Head to Garrarus; and possibly the xenolithic felsites and greenish tuffs belong to the same series. It is doubtful whether these were poured out before the first folding of the Ordovician beds, but their strike, when traced inland, agrees with that of the series last mentioned. The intrusion of some irregular masses of felsite-porphyry took place subsequently to the folding; it was followed by small veins of trachyte and andesite; these by basic sills, diabases, etc., and by a few dolerite-dykes and veins. Subsequently the igneous intrusions assumed an acid character, and the felsitic masses of Newtown Head, Knockmahon, etc., were extruded; probably at this time, too, were formed the isolated necks filled with brecciated fragments of the earlier rocks. The felspar-porphyry dykes and isolated felsitic sheets and veins which pierce the folded rocks, particularly west of Kilfarrasy, probably belong to this late period.

The relative age of some of the peculiar types of intrusive rocks is indicated in the paper in those cases in which it can be determined. That those rocks which are later in date than the folding of the Ordovician are older than the Upper Old Red Sandstone is shown (1) by the unconformity of the Upper Old Red Sandstone; (2) by the fact that the latter rock does not contain any interbedded igneous rocks; and (3) by the absence of felsitic or other intrusive rocks from the Old Red Sandstone of the district.

The second part of the paper is devoted to petrological notes on the different rock-types. The felsites are classified by means of their groundmass into microcrystalline, cryptocrystalline, and micropoikilitic and other types; potash-felsites, potash-soda-felsites, and keratophyres, all appear to be present; some of these rocks are linked to the trachytes and bostonites. The diabases and dolerites are sometimes ophitic, but more usually allotriomorphic in texture. The trachytes and andesites are of various types, and some are probably keratophyres. Quartz- and felspar-porphyries, augite-porphyrites, and several miscellaneous types are also described.

2. "On a new Type of Rock from Kentallen and elsewhere, and its Relations to other Igneous Rocks in Argyllshire." By J. B. Hill, Esq., R.N., and H. Kynaston, Esq., B.A., F.G.S. (Communicated by permission of the Director-General of H.M. Geological Survey.)

A rock originally described by Mr. Teall from Kentallen is used by the authors as a type round which they group a peculiar series of basic rocks discovered in several localities. The rocks consist essentially of olivine and augite, with smaller amounts of orthoclase, plagioclase, and biotite, while apatite and magnetite are accessory. The peculiar feature of the rocks is the association of alkali-felspar with olivine and augite, and the group is related to the shonkinite of Montana and the olivine-monzonite of Scandinavia. The occurrence of the rocks is connected with four neighbouring but distinct areas of intrusion, each characterized by granites and diorites, and by dykes and sills of lamprophyres, porphyrites, etc. In these areas the new rock is the most basic type, and it occurs in the marginal portions of the areas. Close relationships exist between the different intrusive rocks in each area, so that it may be concluded that these constitute a 'rock-series' ranging from granite through augite-diorite towards the olivine-bearing rocks, in the plutonic phase, and from orthoclase-porphyry and porphyrite to augite-lamprophyre, in the dyke-and-sill phase. The whole assemblage appears to have been derived by a process of differentiation from one parent magma; and the order of intrusion has been, in the main, one of increasing acidity. There is further a 'facies-suit' in each intrusion, showing progressive increase in basicity from centre to magma, due to concentration of the more basic oxides in the cooler portions of the magma, which was originally of intermediate composition; from this 'complementary rocks' were produced. It is extremely probable that the underlying magmas of the four intrusive areas resembled one another more or less closely in composition.

II.—June 6, 1900.—J. J. H. Teall, Esq., M.A., F.R.S., President, in the Chair. The following communications were read:—

1. "Mechanically-formed Limestones from Junagadh and other Localities." By Dr. J. W. Evans, LL.B., F.G.S.

After reviewing the conditions under which granular limestones may be accumulated by current- or wind-action, the author proceeds to describe the limestone of Junagadh, a deposit some 200 feet thick, resembling in hand-specimens the Oolites of this country, though less firmly cemented together. It is mainly formed of grains consisting of a nucleus of a fragment of a marine organism or foraminiferal test, surrounded by a layer of deposited carbonate of lime. Particles derived from the igneous rocks of the neighbourhood and rounded quartz-grains also occur, but amount to only a small percentage of the rock. The whole is bound together by colourless calcite-cement. The deposit is situate at a distance of 30 miles from the sea, and contains no large fossils of any kind.

Calcareous rocks of similar character are described from other parts of Kathiawad, Kach, the south-eastern coast of Arabia, and the Persian Gulf; some of these contain unbroken marine shells and other fossils. These beds are included by Dr. H. J. Carter under the name of miliolite, on account of the frequent presence in them of the genus *Miliola*.

The author discusses the origin of these deposits, and comes to the conclusion that the grains were formed in sea-water saturated with carbonate of lime: some being deposited by currents in shallow water, and others thrown up as a calcareous beach, from which a portion were sifted out by the wind and blown inland to form æolian deposits, as contended by Professor Blake in the case of certain superficial limestones in Kach. The Junagadh limestone falls into the last group, but must have been formed when the land was at a low level and the sea-shore was at no great distance.

A rapid survey is then taken of similar rocks in other parts of the world, which may be grouped into the same three classes. The remarkable wind-blown foraminiferal deposit of Dog's Bay (Galway) is referred to in some detail; and the author concludes by suggesting that in the Oolites of the Jurassic period we have representatives of all three groups.

2. "Note on the consolidated Æolian Sands of Kathiawad." By Frederick Chapman, Esq., A.L.S., F.R.M.S. (Communicated by Dr. J. W. Evans, LL.B., F.G.S.)

The name miliolite-formation was originally given by Dr. H. J. Carter to certain granular calcareous deposits occurring on the coast-line between the peninsula of India and the mouth of the Indus. The foraminifera and other organic remains in the rocks must have inhabited moderately shallow to littoral marine areas. The minute granules are worn and polished; the prevailing genera of foraminifera are roundish, and would be easily moved by wind; remains of larger organisms are absent; and the deposits are false-bedded. All these phenomena are explicable if the deposits represent the accumulation of material derived from littoral calcareous sand of